Environmental Noise Management

An Orientation Handbook for Army Facilities

January 1998

U.S. Army Center for Health Promotion and Preventive Medicine

FOREWORD

Environmental Noise Management: An Orientation Handbook for Army Facilities provides practical information on creating, maintaining, and participating in environmental noise management programs at an Army installation. Its target audience is Army military and civilian personnel who have environmental noise management duties and responsibilities, but who have little experience or applied knowledge in these areas. More experienced personnel, and those elements either indirectly or infrequently involved in environmental noise management programs, may find some parts useful as a basic refresher.

Whatever your job, one of your responsibilities is to know, understand, and implement current Army environmental policy and official guidance. This handbook provides overviews of relevant Federal and Army environmental regulations, policy, and guidance to assist you in obtaining and understanding these documents. These summaries are supplemented by practical experience form seasoned installation personnel. As an orientation, rather than a "how-to" handbook, it intentionally avoids going into the technical details.

This handbook is an ongoing team effort involving experienced Army personnel, staff, and YOU. Your experiences are needed to improve and revise it. Because regulations are changing rapidly, Army facilities vary widely, and the range of duties involved is broad, this environmental noise management handbook may contain information that is outdated or inappropriate for your situation. The handbook is only intended to give a snapshot of current regulations at the time of its writing. Your MACOM Environmental Office, the Army Center for Health Promotion and Preventive Medicine, and other sources mentioned in this handbook can help you keep up-to-date.

ACKNOWLEDGMENT

The manual is a product of a team approach to a need for a basic Army noise management reference. The principal authors are Dr. George A. Luz and Mr. William A. Russell, Jr. Environmental Noise Program, U.S.Army Center for Health Promotion and Preventive Medicine (USACHPPM). The USACHPPM Special Document Office helped in final report preparation.

Thanks to Dr. Larry Pater, U.S. Army Construction Engineering Research Laboratories, Dr. Nelson A. Lewis and Ms. Catherine M. Stewart, Environmental Noise Program, USACHPPM for providing review and comments.

SUGGESTED IMPROVEMENTS

This is a dynamic document that will benefit from the experiences of its users. Please help with suggestions for the continuous improvement of this handbook by sending your comments to Commander, U.S. Army Center for Health Promotion and Preventive Medicine, 5158 Blackhawk Road, ATTN: MCHB-TS-EEN, Aberdeen Proving Ground, MD, 21010-5422 or calling the Environmental Noise Program at DSN 584-3829 or Commercial 410-436-3829 (FAX 410-436-1026) in the continental United States or DSN 584-3829 outside the continental United States.

ENVIRONMENTAL NOISE MANAGEMENT:
An Orientation Handbook for Army Facilities

Table of Contents

INTRODUCTION

"Noise is the most impertinent of all forms of interruption."
Schopenhauer, 1851

"The sound of freedom…"
How USAREUR personnel describe helicopter noise to their German colleagues.

So which is it? A rude irritation or the inescapable price we pay for living the good life? The word noise defies exact definition. One of the most challenging things about noise management is that people's reactions to sound vary widely. For some, it is the insidious "drip,

drip, drip" of a leaky faucet in the dead of night; for others it is artillery blasting a thousand feet away. The dictionary definition of noise is "a loud sound"; "any sound that is undesired or interferes with one's hearing of something." Noise pollution is defined as "environmental pollution consisting of annoying or harmful noise (as of automobiles or jet planes)." The Army produces a number of "sounds" that are considered noise or noise pollution by those within the military community, as well as those who live and work around the installation.

There's no way around it. Though facilities and activities can be sited to lessen noise impact and limited constraints on night operations may be possible in some circumstances, running an Army is a noisy business. The keys to successfully managing environmental noise at an installation are to define the noise impacts, prevent or lessen them if possible, and then communicate clearly and truthfully, early and often, with the affected population.

WHAT IS NOISE?

As stated previously noise is defined as unwanted sound. Sound is the variation of the air pressure about a mean atmospheric pressure (14.7 pounds per square inch). The variations in the atmospheric pressure are expressed in units of Pascals (100,000 Pascals equals 14.7 pounds per square inch). These can range from approximately 0.0006 Pascals for a whisper at 1.5 meters to 1,000 Pascals for firing of a M16 rifle at the firer's ear. Because of this large range, sound pressure is not a convenient means of describing relative loudness of sound. The human ear responds more closely to a logarithmic scale and not a linear scale. Therefore, a sound pressure level is defined as 20 times the common logarithm (base 10) of the ratio of the sound pressure to the reference pressure (0.00002 Pascal). These sound pressure levels are expressed as decibels (dB). A change in noise level of about 9 dB represents roughly a factor of two in apparent loudness, regardless of absolute level.

Since decibels are a logarithmic number, they cannot be added using standard arithmetic. That is, 65 decibels plus 60 decibels are not equal to 125 decibels. To add decibels, it is first necessary to convert the sound pressure levels to acoustic energy. This is done by dividing the decibels by 10 and computing the inverse logarithm of this number. For example, 65 decibels is equal to 10 to the 6.5 power that is equal to 3,162,278 and 60 decibels is equal to 1,000,000. These acoustic energies are summed (3,162,278 + 1,000,000 = 4,162,278). The common logarithm of 4,162,278 is 6.6. This number is multiplied by 10 to obtain the decibel sum or 66 dB.

In environmental noise, the sound pressure level is measured using a frequency weighting network of the sound level meter. One characteristic of sound is the frequency, or pitch. Only sound that humans can hear should be included in a measurement of sound level for purposes of characterizing impact. The human ear is more sensitive to sounds of about 1,000 to 3,000 Hertz and less sensitive at higher and lower frequencies. Therefore, it is appropriate to apply a weighting function to the noise spectrum that will approximate the response of the human ear. The A-weighting frequency network of the sound level meter de-emphasizes the lower and higher frequency portion of the noise spectrum to approximate the human ear's response. The American National Standards Institute (ANSI) specifies the A-weighted frequency response (ANSI 1983). The A-weighting network is used to evaluate transportation (vehicle and aircraft), small arms, and continuous noise sources. The sound pressure levels measured using the A-weighting network are expressed as dBA. A-weighting is not necessarily appropriate for species other than human, since animals have quite a different hearing range and sensitivity.

To assess the annoyance caused by low frequency vibration of structures, the C-weighting network is used to evaluate impulsive noise. Impulsive noise is generated weapons larger than small arms (eg. armor, mortars and artillery) and demolition. This weighting is specified by the ANSI (1986) standard. The sound pressure levels measured using the C-weighting are expressed as dBC.

A more detailed discussion of noise and the metrics used to evaluate environmental noise are presented in Appendix A.

CHAPTER 1: LAWS AND REGULATIONS

A simple rule of environmental management is to always start with a disclaimer or two. Disclaimer #1: this handbook is not about hearing hazards or occupational exposure to noise. It is about environmental noise as defined by the Noise Control Act of 1972 (U.S. Congress 1972). Disclaimer #2: this first chapter goes into a fair amount of detail about the various Federal laws that regulate noise. Read to gain a "big picture" of noise control, but realize that the Federal law in this area is of little significance. Few specific regulations controlling noise sources have been promulgated under Federal law. Many State and local governments do enforce noise restrictions, but Department of the Army (DA) lawyers have concluded that "the precise extent to which a State or local government may regulate the noise of a Federal agency under section 4 of the Noise Control Act is unclear" (U.S. Army 1989).

Don't take any of this to mean you're off the hook, however. Noise management in the Army is a very serious business and is definitely and definitively regulated by Army Regulation (AR) 200-1 (U.S. Army 1997). As an unpublished Army Environmental Policy Institute (AEPI) study pointed out, 43 percent of installations surveyed reported noise problems that required either rescheduling or moving training ranges to resolve. An Army installation has to coexist in peace with neighboring communities and local governments to retain its ability to train for its war-fighting mission. Most Army installations also have to make a fair amount of noise to perform their missions successfully. Balancing these two requirements takes an organized noise program — which it is your job to put together and make work.

An important concept to begin with is the distinction between laws regulating the amount of noise emitted from equipment (emissions laws) and laws regulating the amount of noise exposure received at specific locations (receiver-based laws).

EMISSIONS LAWS

Emissions laws and regulations regulate noise at the source. One important set of noise regulations in the United States is the Federal Aviation Administration's (FAA) Title 36 of the Code of Federal Regulations (CFR), which gives the requirements for a Stage 2 and Stage 3 aircraft (Stage 3 is the quietest). By setting deadlines for the replacement of Stage 1 with Stage 2 aircraft and of Stage 2 with Stage 3 aircraft, the FAA has systematically reduced the amount of aircraft noise generated from commercial airports. Congress exempted the military from this category of law because noise controls could, in some cases, reduce the combat effectiveness of military equipment.

RECEIVER-BASED LAWS

Receiver-based laws regulate the noise levels received at a particular site. A typical receiver-based law is that of the State of Illinois (Illinois 1982). This law distinguishes between three classes of land use: Class A (residential); Class B (commercial); and Class C (industrial). Different limits are prescribed depending on whether the noise source is located on Class A, B or C land and depending on what kind of land is receiving the noise. Table 1-1 shows the allowable limits for impulsive noise specified in the March 1982 version of the Illinois law.

Table 1-1: Example of Receiver-based Noise Law — Illinois

Classification of Land Use	Allowable Limit at Boundary of Receiving Land		
	Class B	Class A	
		Day	Night
Residential (Class A)	50	50	45
Commercial (Class B)	57	50	45
Industrial (Class C)	61	56	46

Values are in decibels, A-weighted as measured with a Type I or Type II sound-level meter set to a fast reading.

An example of where the Illinois law has been applied is Rock Island Arsenal, which is located on an island between Iowa and Illinois. Impulsive noise from the Arsenal propagates into both States, but since Iowa has no law governing impulsive noise, half the noise is unregulated. On the Illinois side, however, the Arsenal is in Class C land. Thus, the noise limits are 61 decibels (dB), A-weighted, set to a fast reading (dBA, fast) for commercial zoning and 56 dBA fast for residential zoning. This situation at the Arsenal is a good example of why environmental managers should consult their Staff Judge Advocate (SJA) to decide whether a noise law applies. For example, since the Noise Control Act (NCA) exempts the noise of combat material from regulation, can the Illinois law be used to regulate the test firing of a 105 millimeter howitzer being repaired at the Arsenal? Does the law apply to the impulsive noise generated by the Arsenal's powder gymnasticator (a device used to test the howitzer recoil mechanism without actually firing the gun)?

Another example of a receiver-based law is in the State of Washington. Washington State has many noise regulations, but the one most pertinent to the Army and applies to Fort Lewis is the Washington Maximum Environmental Noise Levels (Washington State 1987). The regulation establishes maximum noise levels in A-weighted decibels (dBA) that shall not be exceeded in identified land uses, and by that provides use standards relating to the reception of noise within those land uses. These noise limitations in can impact range operations. Table 1-2 summarizes these limitations after conversion of the A-weighted levels to C-weighted peak levels.

Table. 1-2. C-Weighted Limitations as Applied in Washington State

Receiving Class	Limitation Can Not Exceed More Than Per Hour	C-Weighted Peak
A - Residential	90 events 300 events 900 events	120 115 110

Receiving Class	Limitation Can Not Exceed More Than Per Hour	C-Weighted Peak
B- Commercial	90 events	125
	300 events	120
	900 events	115
C - Industrial	90 events	130
	300 events	125
	900 events	120

Based on actual monitoring Fort Lewis could easily reach the limitation of 90 events per hour in the receiving classes A and B during major training exercises. This would be particularly true during time on target training.

NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)

The history of the regulation of "noise pollution" from Army activities begins with the passage of the National Environmental Policy Act (NEPA) of 1969 Public Law (PL) 91-190 (U.S. Congress 1969). NEPA is the nation's charter for protecting the environment. Prior to NEPA, the only way that citizens could seek relief from military noise was through "property-based remedies" and "tort-based remedies" both of which involved lawsuits in Federal courts.

NEPA mandated the environmental impact assessment process for Federally supported or sponsored projects. Noise is one of the many environmental attributes considered during the NEPA process. All Federal agencies, including Army installations, must consider and document the noise impacts associated with proposed actions.

The passage of NEPA posed more of a problem for the Army than for the sister services, for there were no scientifically accepted procedures for describing the consequences of exposure to the explosions of large weapons or small arms. In contrast, the U.S. Air Force (USAF) had been funding research into the effects of aircraft noise since the late 1950s and had adopted an aircraft noise assessment methodology known as the Composite Noise Rating (CNR) in 1964. Although the Army was able to adapt the CNR method to helicopters, a methodology for weapons noise was not approved until the late 1970s.

Army noise managers should be aware of the following key points regarding NEPA:

- If a significant amount of environmental noise is associated with a proposed action, the commander is legally obligated to consider that noise before making the decision to go ahead with the project.
- If a project is begun without an adequate assessment of environmental noise, citizens can enjoin the commander from further work until an adequate assessment is completed.
- The Federal courts have accepted the use of Department of Defense (DOD) computer models as adequate for assessing environmental noise.
- NEPA does not forbid the Army from making noise. It does, however, obligate the commander to assess the noise, consider ways to reduce the noise if the levels are annoying and unhealthy, and inform the public about the noise before making the final decision to go forward with a project. In addition, the Army must actually implement noise mitigation measures proposed to support the conclusions of NEPA analysis. For

example, if a Finding of No Significant Impact (FONSI) is made based on proposed noise mitigation measures that will be built into the proposed project, then those mitigation measures must be built as promised. This obligation opens installations to legal review or a court injunction if the promised noise mitigation measures are not carried out. For that reason, it's a bad idea to promise NEPA mitigation strategies that lie outside the ultimate control of the installation (e.g., a perpetual no-development zone outside installation boundaries).

NOISE CONTROL ACT (NCA)

The next milestone in the regulation of noise was the Noise Control Act (NCA) of 1972 (PL 92-574) (U.S. Congress 1972). The NCA was passed by Congress specifically to address environmental noise. In NCA section 2(a), Congress found that "inadequately controlled noise presents a growing danger to the health and welfare of the Nation's population, particularly in urban areas." Further, it was the "policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare." In passing the Act, however, Congress recognized that noise abatement and control remained primarily a State and local responsibility.

The Environmental Protection Agency (EPA) was designated as the lead agency for this statute and the Federal clearinghouse for all Federal activity in this area. EPA was to coordinate all noise legislation and policies enacted by Federal agencies, prepare a report to Congress on the effects of noise, and develop a document that would determine what was needed to protect the public health and welfare with an adequate margin of safety (EPA 1974). The EPA would review Federally sponsored projects, policies, and programs that deal with the subject of noise and coordinate this activity through the Office of Noise Abatement and Control (ONAC). ONAC was operational from 1972 until 1984.

The NCA also assigned the EPA responsibility to promulgate noise emission standards, require product labeling, facilitate the development of low noise emission products, assist local and State governments in their abatement efforts, and promote education and research. Without this assistance, many State and local governments would not have survived financially or technically in the noise area. Ten technical assistance centers were established (one in each EPA region) and grants were awarded to States and cities under the Each Community Helping Others (ECHO) program. Model noise ordinances were developed that included land use noise provisions such as zoning, building codes, and site design standards.

Beginning in the early 1980s, however, EPA lost budgetary support for the ONAC program and since 1984 it has operated with only one full-time employee. Consequently, the noise program is not receiving the overall Federal support that was intended at the outset.

Even though the EPA Levels Document guidelines were enacted for the protection of public health, safety, and welfare, they still are considered a goal. Based on health goals rather than either technological or economic feasibility, many organizations, communities, and the like use them as a point of reference. However, EPA never promulgated any environmental noise levels as a specific standard.

RELATED FEDERAL LAWS AND REGULATIONS

Occupational Safety and Health Act (OSHA): The Federal Government first addressed the noise issue of occupational exposures associated with industrial activity under the Occupational Safety and Health Act (OSHA) of 1970 (PL 91-596) (U.S. Congress 1970), administered through the U.S. Department of Labor. Normally OSHA concerns are addressed by the installation safety office or preventive medicine branch. Hearing hazards are the purview of preventive medicine.

Other Related Laws and Regulations: An Aviation Noise Abatement Policy was established by the Federal Aviation Administration (FAA) in 1976 (FAA 1976), applicable to civilian-operated airports. This policy limited communities from taking local action against airports that involved unjust discrimination or an undue burden on interstate commerce or that were arbitrary or capricious. This policy was followed by a 1976 amendment to the Airport and Airway Development Act of 1970 (U.S. Congress 1970) and later by the Aviation Safety and Noise Abatement Act (ASNA) of 1979 (PL 96-193) (U.S. Congress 1980). In general, these laws are implemented by the Department of Transportation (DOT) and the FAA, who set the means for measuring noise, determining exposures, and ensuring compatible land use development.

The regulation that comes closest to paralleling military activity is from CFR Title 14, Part 150, *Airport Noise and Land Use Planning* (cited as "14 CFR Part 150"). 14 CFR Part 150 is a voluntary program for airports to develop compatibility plans for noise control, including both noise exposure maps and noise compatibility programs (NCPs). In many ways this program, which included over 225 airports studies, resembles the earlier Air Installation Compatible Use Zone (AICUZ) and Installation Compatible Use Zone (ICUZ) programs developed by the Air Force, Navy, and Marine Corps. It is considered by some as the civilian version of these military programs. So why do we mention it here? Well, an important part of your job is to protect employees and residents of the Army installation not just from noise generated by Army activities, but from noise coming from *outside* entities as well. This set of regulations would apply when a civilian airport is encroaching on Army property, such as the noise zones II and III on Ft. Bliss caused by the El Paso airport and the Zone II caused by National Airport in Washington DC on the Ft. McNair general officer's housing area.

The Federal Highway Administration (FHA) published regulations on 8 July 1982 in 23 CFR Part 772, "Procedures for Abatement of Highway Traffic Noise and Construction Noise." The State and Federal Government (FHA) are required to provide noise barriers when traffic noise exceeds certain thresholds. This is another set of regulations that should be examined with an eye to protecting the installation from *outside* noise. Ft. Bliss had a traffic noise barrier built for them under these regulations. Ft. Jackson is currently involved in negotiations with their State to extend a traffic noise barrier that was built to protect private homes, but not the military housing right next to it!

CASE LAW

Airport noise was not a significant problem in the early years of aviation. However, the advent of more powerful aircraft and the growth of the air transportation industry exposed increasing numbers of citizens to noise. One of the leading cases in the realm of aircraft flight over private property is United States (military air base) v. Causby (chicken farm), 328 U.S. 256

(1946). There are similar cases in tort-based remedies (e.g., Nuisance and Trespass, Damages and Emotional Distress, Federal Rule, and Statutes of Limitations).

ARMY REGULATIONS AND GUIDANCE

Staff Judge Advocate (SJA) Guidance: The NCA opens the possibility of Army activities being subject to State and local noise regulations. However, the language of the Act is somewhat ambiguous. Rather than try to interpret it, a 3 March 1989 memorandum from the Office of the Judge Advocate General is reproduced in the box at the end of this chapter (U.S. Army 1989).

Army Regulation (AR) 200-1: Chapter 7 of AR 200-1 (U.S. Army 1997) implements all Federal laws concerning environmental noise from Army activities. The cornerstone of the Army regulations on environmental noise is prevention. Just as our troops engage in a constant cycle of maintaining and inspecting every piece of military material, environmental planners maintain an up-to-date description of high noise areas and inspect these areas for threat of encroachment.

The preventive approach evolved out of DOD's experience. Just as military preventive medicine evolved out of the experience of battles lost from disease, the DOD developed the AICUZ program after losing the use of some air bases because of residential encroachment. The program began in 1973. In April 1975, the DOD issued guidelines to identify realistic accident potential zones (APZs) and compatible land uses that could be recommended to appropriate local planning agencies. The DOD's compatible use zones instruction (32 CFR Part 256), issued in January 1977, stressed DOD's intention to take all reasonable, economical, and practical measures to reduce and control flight noise. The DOD then established the "day-night average sound level" (DNL) for describing aircraft noise. It is essential that you understand and can explain to the public what the DNL means and how it is used; an explanation of it is in Appendix A of this handbook. In commenting on the AICUZ effort in 1979, the General Accounting Office (GAO) wrote: "The Department of Defense has a timely, forward-looking program for achieving compatible uses around military airfields."

Initially, the Army's involvement in AICUZ was small. As noted in the 1979 GAO report, "At present the Army does not have an active AICUZ program because its smaller and less noisy aircraft do not have as great an impact on the community as those used by the Navy and Air Force." The Army's real noise problem was heavy weapons noise, but no one knew how to assess blast noise. For this reason, the DOD asked a long-standing committee of the National Research Council (NRC), the Committee on Hearing, Bioacoustics, and Biomechanics (CHABA), to recommend an assessment procedure. In 1981, CHABA Working Group 84 published *Assessment of Community Response to High-Energy Impulsive Sounds.*

In January 1983, the Army established the ICUZ program (U.S. Army 1983) to protect the mission of the installations as well as the public. The goal of the ICUZ program has been to identify noise-impacted areas so that the public and government officials working with the Army in a cooperative manner can develop solutions to problems, thereby minimizing noise impacts through effective land use planning and control.

This program evolved out of the earlier experiences of the U.S. Air Force, Navy, and Marine Corps, which incorporated consideration of aircraft-related noise and accident potential into the AICUZ planning process. Since these branches of the service focused only on aircraft

noise and land use compatibility, the Army ICUZ program is broader in scope. The Army program addresses all sources of noise, including aircraft (fixed and rotary wing), weapons fire, and ordnance. To show that the Army was addressing all sources of incompatible land use, the "Air" was dropped from AICUZ, and the Army's program became known as ICUZ. The program has since become known as the Army's Environmental Noise Management Plan (ENMP) rather than the ICUZ Program (U.S. Army 1997). The successful implementation of the Army ENMP carries out the obligation of the DA under the NCA, the Quiet Communities Act, and AR 200-1.

The specific requirements set forth in AR 200-1 may change from time to time as change in law, policies, technological developments, and other factors necessitate revision of the regulation. Be sure you are using the current version of AR 200-1 to determine the general requirements governing your installation's noise program. The information presented in chapter 2 of this handbook will help you understand how specific noise management programs are carried out under AR 200-1.

Army Regulation (AR) 200-2: This regulation (U.S. Army 1988b) deals with compliance with NEPA. The relationship of noise management to NEPA is discussed above. Installations are required by AR 200-2 to integrate the NEPA and ENMP processes.

Related Regulations:

Department of Defense Instruction (DODI) 4165.57, Air Installation Compatible Use Zones of 1977, and *Military Standard, MIL-STD 1474 (C), Noise Limits for Army Material, March 1991:* These documents specifically deal with environmental noise.

Army Regulation (AR) 95-1, Flight Regulations, May 1990: These regulations cover the U.S. Army Noise Abatement—Fly Neighborly Program. The policy covers aircraft operations, crew requirements, and flight rules. It also includes applicable paragraphs of Federal Aviation Regulation Part 91 and 105. The regulation applies to all Army aircraft systems and persons involved in the operation of such aircraft and systems. These include aircraft on loan, lease, and bailment to the Army, The Army National Guard, and the U.S. Army Reserve.

JUDGE ADVOCATE GENERAL MEMORANDUM ON ENVIRONMENTAL NOISE
3 MARCH 1989

1. In section 2(b) of The Noise Control Act of 1972 (the Act), 42 4901 (b), Congress declared "That it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare." In section 4 (a) of the Act, 42 United States Code (U.S.C.) 4903 (a) Congress directed that Federal agencies carry out their programs in such a manner as to further this policy, to the fullest extent consistent with their authority under Federal laws administered by them.

2. Congress further provided in section 4 (b) of the Act, 42 U.S.C. 4903 (b), that Federal agencies "(1) having jurisdiction over any property or facility, or (2) engaged in any activity resulting, or which may result, in the emission of noise, shall comply with Federal, State, interstate, and local requirements respecting the control and abatement of environmental noise to the same extent that any person is subject to such requirements." Congress defined the term "environmental noise" in section 3 (11) of the Act, 42 U.S.C. section 4902 (11), as "the intensity, duration, and the character of sounds from all sources."

3. The First Circuit Court of Appeals concluded in *Romero-Barcelo v. Brown*, 643 F. 2d 835, 855 (1st Cir. 1985) that when Congress used the term "requirements" in section 4 of the Act, Congress meant precise standards capable of uniform application. Therefore, section 4(b) does not encompass "nuisance" laws. The First Circuit also held that an action could not be maintained against a Federal agency for a State law claim under the Act. The court noted without ruling on the issue, however, that it may be possible to maintain an action against an officer of a Federal agency for a violation of a requirement under section 4 of the Act. *Id*.

4. Congress directed the Administrator of the Environmental Protection Agency (EPA) to establish "noise emission standards" for "products" in section 6 of the Act, 42 U.S.C. section 4905. Congress excluded military weapons or equipment designed for combat use, however, from the definition of "product" in section 3 of the Act, 42 U.S.C. 4902.

5. Based upon all the above we can only conclude that the precise extent to which a State or local government may regulate the noise of a Federal agency under section 4 of The Noise Control Act is unclear. An argument can be made that State and local governments may not regulate noise emissions from military weapons or equipment designed for combat use. In fact, based upon the definition of environmental noise, an argument can be made that State and local governments may not regulate the noise emission of any particular Federal agency source, but only the intensity, duration, and character of sound from all sources in general. This distinction, of course, may not be helpful in many situations. Finally, an argument can be made that a State or local government may not permissibly regulate a Federal agency noise source if that source is the only source to which the regulation is applicable.

6. Nonetheless, Congress has expressed a desire that Federal agencies carry out the policy of section 2(b) of the Noise Control Act, and also that Federal agencies seek to comply with Federal, State, and local requirements respecting the control and abatement of environmental noise. In light of this, we think the correct Army policy with respect to the Noise Control Act is that all Army activities should endeavor to comply with all Federal, State, and local requirements respecting the control of noise as stated in section 4(b) of the Act, unless to do so would conflict with the Army's military mission. The obligation to comply with State or local noise laws arises out of the Army's policy of cooperation on environmental matters generally.

7. AR 200-1 requires one change in order to be consistent with this policy. Paragraph 7-5 (b) should read: "Comply with applicable Federal laws and regulations respecting the control and abatement of environmental noise. Questions regarding the applicability of State and local laws and regulations should be referred to the Command legal officer and through channels to DAJA-EL if necessary for ultimate resolution."

CHAPTER 2: THE INSTALLATION PROGRAM

THE PLAYERS AND THEIR ROLES

The Regulators: The EPA is the Federal agency charged with enforcement of the NCA. EPA's policy is to promote an environment for all Americans free from noise that jeopardizes their health and welfare. EPA reviews Federally sponsored projects, policies, and related programs that deal with the subject of noise. It is responsible for promulgating noise emission standards approving product labeling, developing low noise emission products, and assisting State and local governments in their abatement efforts. EPA functions that are national in scope, such as promulgating standards, are carried out by EPA Headquarters. Other functions, such as assisting State and local governments, are carried out by EPA's 10 regional offices. As noted in chapter 1, funding for EPA's Noise Control Program was drastically reduced in the early 1980s, and today, EPA has only a minimal noise program.

Occupational exposures to noise associated with industrial activity is addressed under OSHA, administered through the U.S. Department of Labor. Aviation Noise Abatement Policy, the Airport and Airway Development Act, and the Aviation Safety and Noise Abatement Act are delegated to the FAA and DOT to determine systems for measuring noise, to determine exposures, and to develop the means to ensure compatible land use development.

State or local regulatory agencies go by various titles such as Environmental Protection Agency, Department of Energy and Natural Resources, and the like. The precise extent to which a State or local government (e.g., Department of Public Health, Municipality) may regulate the noise of a Federal agency under section 4 of the NCA is not clear. However, State governments have the responsibility to provide legislation and to assist local governments in planning and implementing land use compatibility strategies. Local governments are responsible for providing and administering most of the actual land use measures.

The regulators are excellent sources of information and assistance. Part of their mission is not only to enforce the law, but to assist the regulated community in complying with the law. They really are there to help you. It pays to cultivate a good working relationship with individuals at all the regulatory agencies involved.

The Army Installation: AR 5-3, Installation Management and Organization, November 1986, goes into great detail about each of the staff elements at a typical installation and the various missions they are tasked to do. This document can be obtained from the installation's Learning Center or library. The Installation Mission and Organization document for your installation can usually be obtained from the installation Executive Officer or Deputy Commander. The paragraphs below discuss who plays a role in the installation's noise program and what they should be tasked to do.

Installation Commander: The Commander is ultimately responsible for the success of the installation noise abatement program. In addition, the commander serves two important roles. First, it is the Commander who possesses the long-term vision of the installation's future development, including changes in weapons, mission, and training doctrine. Second, the commander functions in the same role as a mayor of a small town. Like other mayors engaged in

regional planning, the commander is expected to participate, either directly or through a designated staff member.

Directorate of Public Works (DPW): The Directorate of Public Works (DPW) (formerly called the Directorate of Engineering and Housing (DEH)) plays a great role in an installation noise abatement program. The DPW supervises the Master Planning and Environmental Offices, evaluates management and implementation of the compatibility planning, and solicits assistance for compatibility use zone studies from other Army agencies, including the Major Command (MACOM) and U.S. Army Center for Health Promotion and Preventative Medicine (USACHPPM, formerly known as the U.S. Army Environmental Health Agency).

Environmental Quality Control Committee (EQCC): Under the AR 200-1 requirements that took effect 23 May 1990, installation commanders carry out their responsibility for environmental management through this committee. The regulation may not always specify use of a committee; however, the committee can be an effective mechanism for addressing noise issues at the installation level. Normally, leadership of the EQCC has fallen upon the Environmental Office. It is essential that the responsibility for the Environmental Noise Management Program (ENMP) be shared among the Commander's staff. The committee can be responsible for the following seven functions:

1. Reviewing noise and vibration complaints to determine if there are any patterns. Investigating and recommending mitigative actions for existing and proposed operations that have an impact, either on or off post.
2. Coordinating with the public to educate them on noise, vibration, and how noise affects them.
3. Assessing installation activities for possible noise and vibration impacts, both on and off post.
4. Monitoring land development plans, programs and projects in the area adjacent to the installation for land use changes that are not compatible with the noise or vibration environment. In the case of airfields with runways used by fixed-wing aircraft, responsibility would include the relevant clear zones and accident potential zones as directed by DOD Instruction 4165.57.
5. Reviewing the siting of new on-post facilities to ensure that they will not cause a noise or vibration impact.
6. Reporting findings and potential problems to the installation commander.
7. The committee staff, besides the installation Commander, should include representation from the staff elements described below:

Environmental Manager: An environmental manager in the committee is the most likely person to understand the technical aspects of environmental noise because of the manager's background in science or engineering.

In the beginning years of the Army's noise abatement program, installation environmental staffs were smaller than in the 1990s, and few could afford the luxury of having one person trained in environmental noise. At some installations, it is now possible to have a single technical consultant on all noise matters supervised by the environmental manager or coordinator.

Master Planner: As part of the ENMP the ICUZ study, the key tool to identifying and avoiding potential noise problems at an installation, is essentially a planning document. Army master planners have been part of the noise program from its inception. In 1972, the Army Master Planning Office funded the development of BNOISE, the heavy weapons noise contouring software. Army priorities for Joint Land Use Studies (JLUS), a DOD effort, are determined by the DA Master Planning Office based on input from installation planners. Installation planners are also most likely to coordinate with various off-installation public officials, such as zoning boards and local planning offices. As proponent for the installation long-range master plan, the installation planner is in a good position to work with G-3, range, and airfield operations personnel to develop the future use scenarios needed for ICUZ studies.

Staff Judge Advocate (SJA): The SJA is an interpreter of State and Local noise law. They are also in best position to understand zoning law and know when military noise constitutes a "taking" of the value of a property. When noise complaints escalate into damage claims (e.g., losses of livestock, cracked windows), the SJA has the first step in deciding if a claim is valid. The SJA must work with the environmental noise coordinator to establish the facts.

Because the SJAs are trained to deal with the nuances of language, they are in the best position to edit ENMP studies. Writers of ENMP reports must walk a fine line between telling the community about noise and telling the community how to use its land. The former is authorized under NEPA; the latter is an interference of the Federal government in local government.

Public Affairs Officer (PAO): The Public Affairs Office (PAO) is typically the central point of contact for all noise inquiries or complaints. They also have primary responsibility for organizing and managing all off-post meetings and formal contacts. In environmental matters, the PAO's role in dealing with the public is so important that some PAO staff are being trained in environmental risk communication so they are better able to communicate these complex issues to the public.

Range Control Officer: The Range Control Officer is the person capable of collecting the operational data needed to generate noise contours. If actual data are unavailable (as is likely the case), the Range Control Officer's expertise is essential in coming up with reasonable estimates of firing data. Contact USACHPPM for additional information on data requirements (see chapter 3).

The Range Control Officer usually knows who is complaining about weapons noise and why they are complaining. He is also in the best position to decide whether recommendations for noise mitigation are practical and feasible.

G3/Director of Plans and Operations: The G3 is the expert on the long-range plans for training. The G3 knows about the weapons of the future, where they will be used and how much ammunition they will use. The G3 also has the greatest stake in the success of ICUZ planning and the noise abatement program because the loss of ranges, flight corridors, maneuver and training areas due to off-post encroachment hinders effective training. As some environmental noise committees have discovered, the ENMP process cannot proceed without the blessing of the G3. As a career officer, usually from a branch of combat arms, the G3 is likely to have a different world view from the civilian members of the committee.

Airfield Operations Officer: Just as the Range Control Officer is the source of operational data for the ranges, the Airfield Operations Officer is the source of data for airfield noise. The noise manager must depend on the experience of the Airfield Operations Officer to develop the data or estimates needed for airfield noise contours.

Airfield Operations Officers and PAO are in the best position to know who is complaining about aircraft noise and why. Through the preparation of local flight regulations, they can set up "no fly zones" and minimum altitudes over noise sensitive areas (within FAA limits). Airfield Operations is the point of contact with the Army Aviation Support Agency's "Fly Neighborly" effort. Another role for the Airfield Operations Officer is determining the location of the clear zone and APZs, so that they can be drawn onto the installation master plan.

Preventive Medicine or Environmental Science Officer: Traditionally, environmental noise services within the Army have been provided by staff of the Army Medical Department, primarily USACHPPM through direct coordination with the installation environmental manager. At the same time, the Preventive Medicine or Environmental Science Officer can serve as the link between the installation and USACHPPM.

Tenants: On some installations, most of the noise comes from tenant units. In those cases, it is essential that the tenant activity is represented on the committee. Transient users, such as National Guard and units of sister services should also be included in the process.

Noise Making Activities: Representatives from each unit or activity that makes noise should be invited to attend the committee meetings. While the military units can be represented to some extent by the range control officer (RCO) and G3, they should be invited to meetings at which issues or procedures that may impact their activities are discussed. Civilian elements who contribute to the noise environment should also participate.

Local Community: Some communities have invited an installation representative to participate on their planning boards. Under the Joint Land Use Study (JLUS), the local community can apply to the DOD Office of Economic Adjustment for a matching grant to implement the findings of an ENMP study after the installation releases it. Such "community empowerment" has been successful at Forts Bragg, Campbell and Knox.

The Major Army Command (MACOM) and Department of the Army (DA): As with every other Army program, the noise points of contact at your MACOM and the DA will provide you with technical assistance, clarification of Army policy, and support for funding requests to execute the noise program.

PROGRAM ELEMENTS

Background: Most of the people who manage environmental noise at Army installations had no knowledge of the subject from their college or university training. Their knowledge has been acquired from on-the-job experience, interaction with experts at the Army Center for Health Promotion and Preventive Medicine, and the Army Construction Engineering Research Laboratory and, in some cases, formal training courses funded on an ad-hoc basis by the MACOMs. Although regularly-scheduled environmental noise training is available from the Navy and the Air Force, these other services concentrate on their primary problem, aircraft noise.

Regularly-scheduled training in managing the Army's primary problem, impulsive weapons noise, is not available at this time. Discussions on how to remedy this deficiency have been ongoing for several years. In the meantime, the new manager of environmental noise will have to depend on the existing mechanisms for learning the program elements (as described in Chapter 3). Four elements of the program are: (1) noise abatement planning, (2) noise complaint management, (3) interacting with local and State regulators, and (4) mitigation.

Noise Management Planning — Updating the Environmental Noise Management Plan (ENMP): The first task of the installation's environmental noise manager is to define the problem. There are two aspects to this task. The first is to identify areas where noise levels from military sound sources are high enough to be incompatible with "noise-sensitive uses" such as housing, schools, churches and hospitals. The second is to identify areas where off post civilian sound sources create incompatible noise environments on post. At most Army installations, the first task is primary. In either case, the environmental managers's tool for identifying these areas is computer software for making maps of noise exposure. Input to the software are operational data concerning the location, operating parameters, incidence and time of occurrence of the noise sources. Fortunately, Army environmental offices do not have to learn how to operate the software; the Army Center for Health Promotion and Preventive Medicine provides this service. The installation environmental noise manager does, however, have to work with the airfield operator and the training community to collect the operational data for input to the software.

***Noise Zone Maps*:** Different kinds of noise require different software packages to produce the noise zone map. The software packages are described in Appendix A. A common feature of all the noise zone maps used in the Army is the use of three noise zones to describe land use compatibility. These are:

- Zone I — compatible
- Zone II — normally incompatible
- Zone III — incompatible

The goal of the Army is to have all noise-sensitive land within Zone I.

***Acoustical Criteria*:** Each software package predicts the amount of sound that would be expected to be measured at a particular location over a specific span of time (usually a year or a busy day). The acoustical measure differs with the type of noise. For traffic, aircraft and small arms noise, the level predicted is the A-weighted day-night level (DNL). For heavy weapons, the level predicted is the C-weighted DNL.

The DNL is the method for describing noise recommended by the US Environmental Protection Agency. The reasons for the EPA's decision and a description of DNL are provided in Appendix A. The use of a different weighting, the C-weighting, for heavy weapons allows a way of capturing the most annoying characteristic of tank guns and artillery - house vibrations induced by low frequency sound. Equations are available for predicting the percentage of people who will be annoyed by a particular decibel amount of DNL from different noise sources, and these equations have been used to recommend limits for community noise exposures. Zone II is defined by the noise exposure which would be expected to result in more than 15% of the population describing themselves as "highly annoyed." Zone III is defined by the exposure resulting in more than 39% of the population describing themselves as "highly annoyed."

For aircraft noise, the levels of noise associated with each of these zones were already defined in the AICUZ instruction and in a consensus publication of the Federal Interagency Committee on Urban Noise (FICUN), Guidelines for Considering Noise in Land Planning and Control (June 1980). According to this document, the upper limit of compatibility is normally a DNL of 65 dB (A-weighted). With certain land uses and with architectural mitigation to reduce interior noise levels, compatibility might be extended up to a DNL of 75 dB (A-weighted).

The relationship between noise level and compatibility category adopted by the Army is shown in Table 2-1.

Table 2-1: Land use Planning Guidelines

Noise Zone	Percent Population Highly Annoyed	Noise Limit Transportation and Small Arms ADNL in A-weighted dB	Noise Limit Impulsive CDNL in C-weighted dB
Zone I	<15	<65	<62
Zone II	15 - 39	65 - 75	62 - 70
Zone III	>39	>75	>70

Environmental managers should be aware of **three caveats** when applying Table 2-1.

1. Many of the noise complaints received by installations are from people living in the Zone I. These are people who are living in quiet areas but who are disturbed by infrequent events, such as a helicopter pilot straying from a Nap of the Earth flight corridor and flying low over the complainant's house or a single large detonation of explosives .

2. Just because an exposure is high, it doesn't mean that a person living there is going to complain.

3. These are voluntary standards.

***Using the Noise Zone Map*:** There are three uses for the noise zone map:

1. To describe the environmental consequences of a proposed action in fulfillment of the National Environmental Policy Act.

2. To guide the installation master planner in siting new facilities.

3. To assist civilian government in preventing incompatible land use development near Army installations. The formal document for accomplishing this goal is the Environmental Noise Management Plan (ENMP).

A common question is, "What happens if an installation's noise exceeds the guidelines?" Although AR 200-1 doesn't provide a clear answer to this question, common practice during the first decade of the environmental noise management process was generally as follows:

- If an existing Army housing area is within a Zone II, the condition has generally been ignored. For example, most of the housing at Fort Hamilton, New York, is exposed to a Zone II from New York City traffic noise. As of the end of fiscal year (FY) 93, no noise reduction measures had been funded. Similarly, most of the General Officer housing at Fort McNair in Washington, DC, is in a Zone II from National Airport.

- New Army housing construction has been canceled when the MACOM learned that they were located in a Zone II. When a barracks were built at Fitzsimmons Army Medical Center, Denver, Colorado, in a Zone II from Stapleton Airport, actions were taken to ensure that the interior noise levels were mitigated to within acceptable residential limits.

- When existing civilian housing is within a Zone II, the condition has generally been ignored.

- If existing Army housing is within a Zone III, the area is programmed for replacement. This happened to the Van Horne Housing Area at Fort Bliss (Zone III from El Paso Airport) and to a small housing area at Fort Dix (Zone III from McGuire Air Force Base).

- No Army housing has been built within a Zone III since MACOMs have been receiving copies of installation noise contour maps.

- No Army medical facilities have been built within a Zone III.

- Few examples of civilian housing located within a Zone III from Army operations have been identified. In these cases, it is likely that a commander would decide to reduce noise by modifying operations or mitigating noise in some other way.

Using Noise Zone Maps in the ENMP

The noise zone map is the technical "heart" of the ENMP is the central feature of the Army's environmental noise management effort. Through the ENMP, the Army communicates with local government to prevent future problems by present planning. An important feature of Army policy since the inception of noise planning has been consistency between on-post and off-post policy. Without this consistency, the Army would lose credibility before local civilian planning and zoning boards. For example, if a developer seeking to build within an off-post Zone II could demonstrate that the Army had put up comparable construction within an on-post Zone II, neither the zoning board nor the Army could argue against the off-post construction on the basis of potential noise impacts.

Steps to Updating the Environmental Noise Management Plan:

Step 1 — Prepare or Update Noise Contour Maps: Identify all military noise sources, with particular emphasis on aircraft and weapons fire activity. The USACHPPM will assist the installation in this matter.

Prepare a zone map in accordance with the DNL noise descriptor method and other guidance or instruction.

If you assume that the installation's Zones II and III will go beyond the installation boundary even after mitigating adjustments, then consider either formally or informally notifying the public of the Army's intent to begin preparing or updating the ENMP. Providing the purpose and methodology and asking their assistance in obtaining needed data. The Environmental Quality Control Committee (EQCC) should be an integral part of this process.

USACHPPM will develop the zone map in coordination with the installation. The MACOM will provide the authority to USACHPPM to coordinate directly with the installation and will also provide the request for this action to be taken. Develop the noise contours for both present and known future Army activities at this stage. You must provide USACHPPM with all information needed to produce contours.

Step 2 — Identify Incompatible Land Uses: Identify all noise-sensitive land uses that are not in compliance with recommended compatibility guidelines. Responsible parties include installations, USACHPPM, and local public planning offices.

Overlay zone maps over the installation map. Where Zones II and III overlap off-post properties, identify those properties on a larger scale map and rate their sensitivity to the corresponding zone in which they lie. Criteria for rating will be those from Guidelines for Considering Noise in Land Use Planning and Control by the Federal Interagency Committee on Urban Noise (FICUN 1980).

Areas on post that fall into Zone II or III will be subject to a separate review under the requirements of the *DOD Construction Criteria Manual 42701.M* and *TM 5-803-2*. Help on obtaining these documents is available from the Army Environmental Response Line at (800) 872-3845 in the Continental United States or DSN 584-1699 outside the Continental United States.

Step 3 — Prepare a Draft ENMP: The draft ENMP plan will consist of eight chapters:

- Chapter I Introduction
- Chapter II Installation and The Community
- Chapter III The Environmental Noise Management Plan
  - Education
  - Noise Complaint Management
  - ICUZ
  - Land Use Guidelines
  - Noise Zones
  - Accident Potential Zones
  - Joint Land Use Studies
  - Noise Mitigation
  - Vibration
- Chapter IV Installation Operations
- Chapter V Environmental Noise Management Plan Implications
- Chapter VI Army and Community Responsibilities
- Chapter VII Community Involvement
- Chapter VIII References

The ENMP identifies existing and potential incompatible lands within Zones II and III off-post. Data will include an estimate of land values and an indication of the types of development that would be desirable and compatible with the zone in which they fall. Recommendations will include means of reducing the noise, thereby eliminating or reducing the impact off-post. Consideration will be given to relocating sources, installing sound suppression measures, regulating operating hours, and the like, within mission requirements. If mitigation cannot suitably reduce the impact off-post, then the recommendation should be to initiate off-post coordination. It is the installation's responsibility to develop mitigative alternatives. USACHPPM will assist in evaluating alternatives in conjunction with the installation and provide that advice as part of the report.

See chapter 3 for resources that may be able to provide technical assistance in preparing the ENMP.

Step 4 — Installation Staff Review: The draft ENMP will be submitted to the EQCC, and Installation Planning Board for their comments.

Step 5 — Prepare ENMP: Incorporate the comments and those mitigating alternatives found acceptable by the installation staff into the plan.

Step 6 — MACOM Review: If there is no off-post noise problem, the ENMP is final and you can proceed to Step 7. If there is a off-post controversial noise problem, the ENMP should be submitted to the MACOM. The MACOM will review for validity of the noise assessment, the feasibility of mitigating alternatives, and the legal ramifications of the report. Upon completion of its review, MACOM will return the report to the installation. The installation will review the MACOM comments and adjust the ENMP appropriately

Step 7 — Community Involvement: A solid relationship between the installation and community should be the foundation for a successful ENMP. Connection with the professional planning community, including State, regional, metropolitan area, and local planners, is essential. Land use information and data from all perspectives should be shared.

Education and communication are the keys to any successful public involvement process, with "peace" at the positive end of the spectrum and "war/terrorism" at the other. Consider a wide variety of citizen participation techniques. Each technique satisfies a set of objectives (i.e., responsibility, responsiveness, and effectiveness). Each technique has problem solving/decision making potential with positive and negative characteristics. The most appropriate technique for a situation needs to be selected with care. Involve the PAO in determining the best approach to public involvement at your installation.

Public participation often remains the weak link in noise management at Army installations.

Review the identity of all the involved "publics" carefully before initiating a program of action. There can be a good deal of role playing in this process since each public has a particular position, objectives, and strategy. Ultimately, the degree of success an ENMP can achieve is linked to the communication and problem-solving efforts that are developed and initiated with surrounding communities. Such a process should not begin and end with the ENMP program, but rather be in place on a permanent basis involving the diverse interest groups within the overall community.

Finally, communication with the local community is not a one-shot deal. Continuous, effective coordination with the local community is required to make sure that "spot" encroachment does not occur into known Zone IIIs. A true story provides an excellent example: A private home was built 2 years ago within an off-post *known* Zone III from a small caliber ammunition test range at an Army ammunition plant. Although the property was zoned agricultural, the local government granted a site variance to the owner to build the home. Local government had assured the installation that development would not be approved within high-noise areas; however, a Memorandum of Agreement was not in effect to document this agreement, nor was the installation notified of the proposed variance. The moral of the story is public participation often remains the weak link in noise management at Army installations. You can't go through the ENMP process once and then forget about interacting with the locals. "Eternal vigilance" is a good motto for the Army noise manager.

Step 8 — EQCC Approval: The EQCC will review the public comments, make their assessment, and provide their recommendations.

Step 9 — Implement Mitigation Actions: The installation will implement those mitigating actions that it can. Actions requiring MACOM or higher approval will be implemented as approval and funding are received. A primer on noise mitigation is presented later in this chapter.

Step 10 — Release Official Report to Public: Upon approval of the ENMP by the installation commander, a copy will be officially provided to City, County and State officials and planning/zoning boards. Media can play an important role in informing all parties of the ENMP. The appropriate public officials will be kept advised of all mitigating actions. Where installation- recommended mitigating actions cannot be performed due to mission or monetary constraints, the public will be advised and recommended to review their zoning ordinances to assure compatibility with the noise zone. USACHPPM will provide technical testimony at public hearings and training to installation personnel, as requested. This service is provided on a cost reimbursable basis and should be scheduled as soon as an off-post noise problem is recognized.

Step 11 — Review and Update the ENMP: No document should be considered static. The ICUZ study requires constant review and updating, depending upon the specific situation. In the past it has been Army policy to revise the ICUZ study every 5 years. The installation should review the ENMP annually for changes required by on- or off-post development and/or by installation mission.

Integrating ENMP into Installation Business

By design, noise program documents such as the ENMP should be living documents, integrated into an installation's other planning programs: training, land management, and master planning. A successful installation noise manager has to be actively involved in the review, if not the development, of the installation's annual and monthly training plans, the integrated natural resources training plan, and the installation master plan.

Also, where Army and Air Force installations are adjacent to each other, a regional, comprehensive approach to noise management must be used. The Army and Air Force bases

need to develop partnerships to achieve a more truly representative noise contour footprint. The public cannot discriminate between the different noise sources.

Contracting ENMP Studies

An alternative to contracting with outside consultants/firms is to contract with USACHPPM. USACHPPM has over 25 years of expert experience in the environmental noise field, including management, education, assessment, mitigation, and noise and vibration measurement. This can be accomplished using the Military Interdepartmental Purchase Request (MIPR) DD Form 448.

Some installations have contracted with outside consultants/firms to develop their ICUZ studies. The following list of "**do's and don'ts**" is based on this past experience:

- Make sure that the government doesn't pay for the same material twice. Much of the background material duplicates text found in the past environmental assessments. If the contractor knows that this material is already available, the ENMP study can cost less.
- If you want the contractor to generate the noise contours, make sure that the work has not already been done by the USACHPPM. At some installations, personnel turnover and poor filing have resulted in the loss of "institutional memory." Without memory of past USACHPPM products, an environmental manager may inadvertently contract to duplicate noise contours.
- Discuss requirements for operational data with range control and air operations before writing the contract. There are no Army regulations requiring range control or airfield operations to keep the operational data required for computer models such as NOISEMAP and BNOISE. Consequently, a person collecting operational data must be fairly sophisticated about Army material, operations, and training doctrine.
- Choose a contractor with a proven track record working with local government and the public. The finest ENMP study is useless if the public rejects it or if the local government refuses to participate in joint land planning.
- If possible, involve all the members of the EQCC committee in the process of choosing the contractor. In the past, some installations have had the process derailed because a key member of the committee was uncomfortable with the product and set up a roadblock.

Noise Complaint Management/Community Relations: The second element of Army ENMP efforts is a complaint management program. Noise complaints should be carefully studied and responded to in a judicious manner. The program must have integrity so that when you tell the community something, the community will believe and trust you. The program must also be sensitive to the community's concerns. Listen to them and find out what is annoying them.

A successful noise complaint management procedure will assist the installation in avoiding community action against its activities. This procedure should be proactive. A specific office to which noise complaints are made and where questions about operations are answered can provide improved community relations. The PAO is a good choice to handle this type of concern.

The potential for noise complaints can be reduced by providing the news media with press releases when "other than normal" operations are scheduled or when normal operations

resume after a period of inactivity. The press release should include a telephone number that the community can use to receive additional information or to complain about the noise.

If the installation does not respond to the complaints in a timely and polite fashion, the complainants may organize into citizen action groups. These groups will raise the complaint to higher levels of command and government.

A noise complaint management procedure should include, at a minimum, the elements described below:

- A log of all noise complaints should be maintained. The log should contain the complaint location, date, time, cause of complaint, and meteorological conditions (for example, wind speed and direction, temperature, cloud cover, precipitation).
- Complaints should be investigated without delay. By investigating complaints immediately, it may be possible to delay the cause of the complaint until noise propagation conditions improve. This action will reduce the risk of additional complaints and will show the complainant that the Army is concerned about their health and welfare.
- The complainant should be made aware of the installation's mission and that every effort will be made to correct the problem, mission permitting. Installation representatives should visit with the complainant and explain the operation, including why it is being performed at this time.
- Complaints should be routed to the office responsible for the type of activity that resulted in the noise complaint. The PAO will require a response to provide information to the complainant.
- If someone other than noise program manager, such as the PAO, receives the complaints a copy of the complaint and response should be provided to the noise program manager. The noise program manager will provide technical assistance to the PAO and the activity generating the noise, with support from the EQCC, as appropriate.
- The noise-generating activity should follow-up by identifying the cause of the noise and action taken to correct any deficiencies found. A copy of the follow-up documentation should be provided to the noise program manager.

Monitoring in Support of Complaint Management: Under AR 200-1, on-site monitoring of the noise environment should not be considered because of the large resource commitments in time, staffing, and equipment required. On the other hand, on-site monitoring may be warranted to verify noise levels that have produced major public and/or political controversy.

There are four other circumstances when short term monitoring may be useful. These are: (1) checking the accuracy of a noise contour at selected points; (2) defining the DNL when no operational data are available; (3) defining the DNL when the model is known to be inaccurate; and (4) defining the baseline DNL. Permanent, unstaffed monitoring equipment provides statistically better data and is far less labor intensive than repetitive monitoring with portable sound level meters. Most automated monitoring of the Army environmental noise can be conducted by the experts at the USACHPPM. Installations with permanent weapons noise monitoring systems include Aberdeen Proving Ground, Picatinny Arsenal, Camp Butner, Camp Grayling, Fort Drum, Fort Carson, Fort Riley, Fort Richardson, and McAlester Army Depot. This permanent long-term monitoring is useful for complaint and damage claim management.

Interacting with the Local and State Regulators: The third element of Army noise abatement efforts is interacting with regulators. Because there are only a handful of State or local noise ordinances applicable to military noise, negative interactions, such as fines and injunctions, are not likely. There is, however, an opportunity for positive interaction through the Joint Land Use Study (JLUS). The JLUS is managed by the DOD's Office of Economic Adjustment, and it is applicable only to installations that successfully completed their AICUZ or ENMP and regions where local government is truly interested in joint land use planning. The JLUS process enables local governments to be more active in the planning process by providing grants for them to hire independent planning consultants. In the process, the outside consultant takes on the role of advising both military installation and local civilian governments. With the JLUS process, communication becomes two-way rather than unilateral.

Most of the JLUS initiatives have involved Air Force installations. A notable exception has been the JLUS for Fort Bragg/Pope Air Force Base. This highly successful JLUS resulted in noise ordinances to regulate development in noise and safety zones, both for aircraft noise and heavy weapons noise. In addition, the cooperative working relationship developed out of the JLUS gave a new impetus to planning in other areas, such as sewage, water, and forest management. Chapter 3 of *Joint Compatible Land Use Policy: Recommendations to Military Jurisdictions and Local Governments in the Fort Bragg Region* gives good information on community relations plans and implementing a joint land use compatibility program (University of North Carolina 1991).

PRIMER ON NOISE MITIGATION

The fourth element of Army noise management is mitigation. Long-range planning through the ENMP and JLUS is intended to prevent noise problems from developing. However, some installations are located in areas that are already developed where existing noise may be at levels annoying to the neighboring population. In some of these cases, it may be possible to mitigate the noise. The Army's environmental noise management program goal is to achieve compliance with applicable noise regulations in a manner consistent with mission accomplishment. To achieve this goal, the Army, within the scope of the Army Environmental Noise Management Program, will do the following:

- Control environmental noise and vibration to protect the health and welfare of people, on- and off-post, impacted by all Army-produced noise, including on- and off- post noise sources.
- Reduce community annoyance from environmental noise and vibration to the extent feasible, consistent with Army training and materiel testing activities.
- Evaluate and control the impact of environmental noise and vibration on the existing and potential habitat of endangered and threatened species.

Mitigation projects generally require the expertise of an acoustical engineer. Acoustical engineers commonly classify mitigation into three categories: source, path and receiver.

Mitigation at the Source: Source mitigation reduces the amount of noise emitted by a piece of equipment or operation. Examples include the following:

Reducing the Number of Operations: The simplest form of source mitigation is reducing the number of noisy operations. During the 1980s, there was some reduction due to

improvements in training. For example, armor crews are training more but making less noise because they fire fewer tank main gun rounds. Instead, crews do some training by firing subcaliber rounds at miniature targets. Other training is conducted in computer-controlled simulators. Helicopter pilots also train for combat missions on simulators, saving the cost of expensive operations and eliminating noise at the same time.

With the DNL methodology, the effective number of operations can be reduced by shifting night operations from "after 2200" to "before 2200." A sound made after 2200 contributes as much to the DNL as 10 sounds of equal intensity made before 2200. However, application of this mitigation may be limited by mission requirements. Many experts believe that the ability of U.S. forces to fight in darkness was a key element in the Desert Storm victory.

Quieter Helicopters: Just as requirements for night training have increased the DNL at some installations, requirements for less detectable helicopters have decreased the DNL at some airfields. Air mobile operations came of age during the Vietnam Conflict and tacticians discovered that the ability of the Vietnam-era helicopters was a limitation. One solution was the development of Nap-of-the-Earth (NOE) flying, which keeps the noise closer to the ground. A second solution was the development of quieter helicopters.

Acoustic Directivity: Every weapon has a characteristic noise field. This noise field is called acoustic directivity. For example, a 2.75 inch rocket and light assault weapon (LAW) make the most noise to the rear of the firing point. A rifle or tank gun make the most noise in front of the firing point. Sometimes, knowledge of acoustic directivity can be used to reduce the source noise in a particular direction.

Type of Round: Noise from 155 millimeter (mm) artillery training can be reduced by substituting the M804 practice projectile for the M107 HE projectile. Beginning in 1982, this round has been used at Camp Edwards, Massachusetts, to reduce complaints from Cape Cod.

Burial of Charges: Burying explosive charges is a standard practice at Army Material Command (AMC) demolition grounds and it is effective. However, burial cannot be used when detonating cases of small ammunition because an undetonated round may go undetected.

Foam Cover: Combat engineers train with small charges as well as large charges. Aqueous foam is effective in quieting smaller charges. This technology is documented in a November 1981 USACERL study, N-112, Use of Aqueous Foam to Mitigate Demolitions Noise, which demonstrated a reduction of 6 to 10 dB in peak levels (U.S. Army 1981) .

Firing through Foam: In 1981, engineers at the Naval Surface Weapons Center, Dahlgren, VA, demonstrated that the peak sound pressure level of a 7.62 mm rifle blast was reduced by 10 dB or more if fired through a canister of aqueous foam.

Metal Spheres: The U.S. Army Belvoir Research, Development and Engineering Center has used a large metal sphere to attenuate the noise of test charges.

Silencers for Small Arms: In 1997, U.S Army Construction Engineering Research Laboratories (USACERL) engineers demonstrated a prototype low-cost small arms muffler at Camp Dodge, Iowa. The muffler, which uses large diameter plastic drain pipe,

delivers a readily discernable reduction of the muzzle blast. A muffler can be constructed for under $150.

Silencers/Mufflers for Larger Weapons: The earliest work on silencing a large weapon was conducted at Rock Island Arsenal in 1969. An engineer at Benet Weapons Laboratory, Watervliet Arsenal, used a water table to model the "uncorking" of the propellant blast. This improved model confined the initial blast to a small, very strong chamber that formed a high-pressure presuppressor. In 1975, the new design was successfully tested with a 20 mm silencer having a diameter of 11.5 inches and length of 33 inches. In 1983, AVCO developed an alternative design for 105 mm tank gun testing at Camp Edwards, which produced 7 to 11 dB attenuation. In the late 80's this muffler was moved to Aberdeen Proving Ground for testing with the 120 mm tank gun. Although the muffler provided some attenuation, it was damaged by the propellant energy and interfered with testing. Another limitation of this muffler was its weight of 22 metric tons. This weight made the muffler unusable in training. In 1996, the German Ministry of Defense unveiled a mobile large scale sound absorber capable of withstanding the blast of a 120 mm tank gun and a 155 mm howitzer. However, the size and weight were incompatible with training.

Vehicle Mufflers: The use of mufflers to quiet the exhaust of gasoline and diesel-powered vehicles is common knowledge. The NCA exempts equipment designed for use in combat from the definition of product and, by implication, from any regulation of noise emissions. In any case, noise control in the Army vehicles falls within the authority of the Army Tank and Automotive Command.

Noise Cancellation Technology: The availability of low-cost, high-speed, and reliable microprocessors led to enthusiasm about active noise control in the early 1990s. In noise cancellation, a sensor responds to an incoming signal and a microprocessor cancels that signal by putting out a signal that is exactly opposite in phase. At the point that these two signals meet, there is a complete cancellation of noise. The technology was first applied within the military to improve communication in noisy areas (noise canceling microphones). There has been some success in using the technology to create more efficient mufflers on diesel locomotives and urban buses.

Flying Neighborly (HAI 1983): Guidance on how to fly helicopters to make the least amount of noise is provided by the Army Aviation Support Agency. A manual entitled *Fly Neighborly* is published by the Helicopter Association International.

Mitigation Along the Path: Mitigation along the sound propagation path reduces the amount of noise getting through to the receiver.

Barriers for Traffic: One of the commonest forms of mitigation along a sound path is the highway noise barrier. There are many ways to build a barrier and many types of construction material used. Acoustical engineers have access to a large body of literature on barrier design, and advice on construction is generally available from the USACHPPM. Here are a few considerations before requesting a barrier design:

- **Distance:** The effectiveness of a barrier depends on the "path length difference." The "path length difference" is calculated by adding the length of the line from the noise source to the top of the barrier to the length of the line from the top of the barrier to the

receiver. The difference between this sum and the line-of-sight distance without the barrier is the "path length difference." For a maximum path length difference, the barrier must either be close to the source or close to the receiver.

- **Receiver Height:** If the receiver is in a multi-story building and most noise sensitive activities take place on the upper floor(s), it is a waste of money to build a barrier to protect only the first floor. For example, if there is a problem with sleep disturbance from night time truck traffic and the bedrooms are on the second floor, a barrier may not be as cost effective as noise-attenuating windows.
- **Post-Construction Evaluation:** It is good practice to measure the noise levels in the area of interest before and after construction of the barrier. User friendly, labor-saving, automated noise measurement equipment suitable for the post-construction evaluation is available from the USACHPPM.

Barriers for Weapons: Traffic noise barriers can also be effective for reducing noise heard at properties located behind a rifle or pistol range. The efficiency depends on the spectrum of the rifle (5.56 mm or 7.62 mm), which is centered around 500 Hz. With increasing caliber of the gun tube, the spectrum shifts toward higher frequencies. For example, a tank main gun requires a 200-meter high barrier to achieve the same decibel reduction as a 4-meter high barrier provides for a rifle. Thus, barriers are impractical solutions for mitigating the noise of heavy weapons.

Using Ground Impedance: Sound propagating close to the ground or reflecting from the ground can lose some of its energy into the ground. Sound propagates better over "hard" ground than over "soft" ground. FAA studies of helicopter noise have shown that there is less noise from helipads if the sound propagates over grass than over asphalt. A rifle fired from a standing position makes more noise at 100 meters than a rifle fired from a prone position. Thus, when locating small arms ranges near developed land, it is better to site the range in a hollow than at the top of a hill.

Ground impedance also has a role in reducing noise from high explosive artillery rounds. Artillery batteries must train with both proximity detecting (PD) and variable time (VT) fuses. The PD fuse detonates the round when it is near the target, but VT fuses can be set to detonate while the round is still high in the air. The air burst propagates more efficiently than the ground burst, canceling both ground impedance and any barrier effects. If meteorological conditions favor the propagation of noise from the impact area to a community, an artillery unit might consider delaying air bursts until the weather changed.

Distance/Altitude: Increasing the distance between source and receiver is a simple way to reduce noise levels. An acoustical rule-of-thumb is that continuous noise from fixed sources, such as from a generator, decreases by 6 dB for every doubling of distance from the source. In practice, high frequency sound is attenuated faster than 6 dB per doubling of distance because more energy is lost to the air. Also, sound propagates better downwind than upwind.

Noise from straight sections of highway drops by 3 to 4 dB for every doubling of distance. Acousticians refer to highways as "line sources," since the noise reaches the receiver from every point in a line of cars and trucks.

When helicopters are flying directly over a site, the noise decreases by about 5 dB for every doubling of altitude. At sites located to the side of the flight path, however, flying low to the ground can lead to a decrease in helicopter noise from trees and other terrain features.

Using Wind Effects: It is better to locate a small arms range or grenade range downwind of a noise-sensitive area than upwind. This rule-of-thumb does not work beyond 5 kilometers for heavy weapons, since a surface wind in one direction may be overlain at a higher altitude by a wind in the opposite direction.

Avoiding Water: Most people know that low frequency sound will propagate efficiently over the surface of a lake or still sea. This is why fog horns are pitched so low. Demolitions and heavy weapons are low frequency sound sources. Given a choice, these sources should be kept away from a body of water if there are houses on the other side.

Using Forest: Forests have very little effect on the propagation of heavy weapons noise, but they can be useful in attenuating traffic noise and small arms noise. A rule-of-thumb is that the attenuation from each meter of forest is equal to 0.01 dB times the cube root of the frequency. For example, the cube root of 1000 Hz is 10 (i.e., 1000 = 10 x 10 x 10) and a 1000 Hz signal is attenuated by 0.1 dB for each meter of forest. In contrast, the cube root of 27 Hz is 3 and this low frequency signal is attenuated by only 0.03 dB for each meter of forest.

Avoiding Worst Case Blast Propagation: The interaction between the weather and blast noise propagation was known in the 19th Century, but technology to predict worst case propagation was not available until after World War II. Meteorological conditions are important for predicting large charges, such as atomic testing, as well as small charges. The earliest U.S. Army effort to predict worst case blast noise propagation was carried out in the mid-1950s by the Explosives Research Group of the University of Utah. Using strain gauges to measure blasts and weather balloons to measure meteorological variables, this group evaluated every demolition ground operated by the Army Quartermaster Corps. Out of these studies, this group developed a set of guidelines for "good" and "bad" firing conditions. These guidelines reproduced in table 2-2.

Table 2-2: Good and Bad Firing Conditions

Good Conditions	➢ Clear skies with billowy cloud formations, especially during warm periods of the year ➢ A rising barometer immediately following a storm
Bad Conditions	➢ Days of steady winds of 5-10 mph with gusts greater than 20 mph in the direction of nearby residences ➢ Clear days on which "layering" of smoke or fog are observed ➢ Cold, hazy, or foggy mornings ➢ Days following a day when large extremes of temperature (20°C or more) between day and night are noted ➢ Generally high barometer readings with low temperatures

The University of Utah (1958) guidelines are useful in telling us when there will be a worst case condition, but are not useful in telling us where the worst case will occur. Worst case conditions occur as a result of blast noise "focusing." Focusing is caused by the channeling of blast noise through the warm air layer of a temperature inversion, sometimes in combination with wind patterns. When blast noise is focused in one location, its level decreases in other locations.

The area of decreased noise level is known as the "shadow zone." Especially at night, the locations of the focus and shadow are dynamic.

Predicting the location of a focus became easier when Army artillery began using data from radiosonde balloons to correct the trajectory of artillery fire. In 1964, the Ballistics Research Laboratory published a procedure that enabled range officers to predict a focus from the temperature, wind speed, and wind direction data collected by Artillery Meteorological Detachment. This same technology was used to predict blast noise focusing at Aberdeen Proving Ground (U.S. Army 1964).

To improve the ability to follow the dynamism of blast noise focusing, Aberdeen Proving Ground funded further research into blast prediction during the early 1990s. One of the innovations was the use of acoustic sounders that use Doppler shift to continuously plot the location of temperature inversion and wind pattern.

Mitigation at the Receiver: Mitigation at the receiver may involve architectural controls or some other means of reducing psychological annoyance.

Insulating Homes Against Outdoor Noise: Methods for insulating homes against aircraft noise are described in 1976 National Bureau of Standards report (Berendt et al) and a 1989 Navy/FAA report, Guidelines for the Sound Insulation of Residences Exposed to Aircraft Operations. The latter allows the user to estimate the cost of sound insulation for 26 different types of residential construction.

Vented Acoustical Windows: In concrete or masonry buildings, the attenuation of outdoor noise is usually determined by the design of the windows. Urban apartment dwellers, such as those living in military housing at Fort Hamilton, NY, are faced with keeping the windows closed to attenuate the noise or opening the windows and receiving a Zone II or Zone III traffic noise exposure. German engineers, faced with the same problem, developed special windows with acoustically-treated vents. Windows of this type became available in the United States in 1992.

Rattle-Proofing Homes: Occupants of buildings located in areas of high-level impulse noise usually report that the main annoyance factor is the rattle produced by house components upon vibration. This type of noise is associated with flybys of UH-1, AH-1 and CH-47 helicopters and blast over pressure from artillery and other military training operations. A November 1987 CERL report, N-87/24, Expedient Methods for Rattle-Proofing Certain Housing Components, analyzes several different building elements to identify individual components contributing to rattle. Elements studied include windows, doors, wall-mounted objects, bric-a-brac, ductwork, gutters, and light fixtures, among others. This report recommends methods for eliminating or reducing the noise from individual flights.

On-Line Noise Monitoring: A number of U.S. airports use on-line monitoring systems to measure the level of individual flights. Individual monitoring units are located within nearby communities, and the output of the units feeds directly into a central computer at the airport noise control office. Using such monitors, airport operators know whether pilots are following required noise mitigation procedures.

Online blast noise monitoring is more difficult than aircraft noise monitoring, especially in windy areas. Existing blast noise monitors are programmed to continuously scan the

microphone input for an event exceeding a threshold (e.g., a threshold of 115 dB, C-weighted.) When the threshold is exceeded, the software integrates the acoustic energy over the entire period of accedence. By throwing out events that are too short or too long to be a true weapons blast and by accepting only events with an expected difference between peak and the average levels, it is often possible to discriminate between true blasts and other noises.

One way to improve discrimination in blast noise monitoring systems is to position a monitor close to the source and use the close-in monitor to open a "time window" for the monitor located in the community. The "time window" is determined by the number of seconds required for sound to travel from the first to the second monitor. This method was first used in a system developed in the mid-1970s for the Navy in Hawaii. A British system using this technique is also commercially available.

When the noise is reaching the monitors from multiple sources at multiple distances, there is no way to adjust the "time window" to match the source distance. In this case, the source of the gun noise can only be determined if three or more monitors register the sound. By knowing the difference in time of arrival and the speed of sound, it is possible to calculate the location of the gun. In 1996, this type of gun noise monitor began operating in a high crime area of Dallas, Texas.

Wind-induced noise causes many problems for unattended noise monitoring, especially low-frequency artillery blast noise monitoring. The wind can effectively mask the blasts and cause many false events. A method to reduce the false events is a real-time system capable of detecting blasts within wind noise while rejecting nonacoustical noise events caused by wind. The system uses a combination of spectral and correlation methods to achieve the discrimination. The system uses two microphones vertically spaced, the signals from these microphones would be highly correlated in the presence of a horizontally propagating acoustical signal (blast noise), and relatively uncorrelated when there is only wind noise present. Performance testing showed a detection and rejection rate of 97 percent (Benson 1996)

.

Psychological Measures: A number of measures, as listed below, can have a psychological impact on noise mitigation.

- ***Spacing between Events:*** Under the procedures for calculating noise levels, the temporal spacing between intrusive noises is irrelevant. For example, the calculated DNL outside an artillery impact area will be the same if 25 rounds are fired between 1300 and 1400 as if they are fired at the rate of 5 rounds an hour between 1700 and 2200. However, there is reason to believe that annoyance can be reduced by concentrating the firing during a shorter period.
- ***Time of Day:*** Residents are usually more annoyed by noise in the evening than during the day and they are even more annoyed by noise at night than noise during the evening. To account for this difference, U.S. regulators add the 10 dB nighttime penalty. Shifting noise to times when people are least likely to be annoyed is an effective form of mitigation. The Army's ability to take this into account is often limited. Army doctrine emphasizes night training and the Reserve Components are required to train on weekends.
- ***Advance Notice:*** Unlike commercial airports and highways, which generate approximately the same amount of noise from one day to the next, military installations are variable. For example, the highest blast noise levels at Fort Bragg occur during a 2-

week period when Marines train there with 155 mm howitzers. Experience has shown that there are fewer complaints when citizens receive advance notice of noisy training.

- ***Published Cease Operations Times:*** Night operations become a problem when they keep citizens awake. Sporadic and randomly spaced noises, such as artillery fire, can be particularly disturbing to sleep when people are unable to predict the time of the last blast. By publishing cease operations times and rigorously following those times, Commanders can lower the "frustration level" of those whose sleep is disturbed.
- ***Noise Awareness Demonstrations:*** As fewer citizens serve in the Armed Forces, public awareness of how the Army trains and fights is decreasing. At times, the public is opposed to an operation simply out of ignorance. A noise awareness demonstration can be an effective way to deal with such opposition. For example, a demonstration conducted by the Pennsylvania National Guard with the help of the USACHPPM in 1992 helped alleviate concern over the effects of a tank artillery range at Fort Indiantown Gap on the Appalachian Trail. Noise awareness demonstrations are also useful in countering a commonly held belief that ground vibration from Army training can damage foundations. Demonstration with simultaneous measurements of ground vibration, house vibration and sound pressure level are useful in showing the public that the vibrations are not being transmitted through the ground.
- ***Checking for Displacements:*** Some citizens may complain about noise when their real concern is something else. Understanding the true basis for annoyance can help avoid useless mitigation. For example, architectural controls to reduce interior noise may not be needed if the source of annoyance is interference with outdoor activity, such as lawn parties.

Land use Control: In some situations, local government has the power to regulate land use. According to a 1979 publication of the National Association of Counties, *Quiet Communities: Minimizing the Effects of Noise through Land Use Controls*, these powers could include zoning, special permits, special projects, health codes, subdivision regulations, capital improvement programs, building codes, disclosure of noise levels, and public acquisition of land.

When an Army installation incorporates recommendations into an ENMP that pertain to the community, successful implementation must be achieved in conjunction with the local political jurisdiction. A military installation has no authority to implement land use controls (e.g., zoning, subdivision regulations, building codes), as this is the responsibility of the local government. Consequently, to be effective, a strong professional working relationship must be established between the relevant political entities and the installation.

An excellent indicator of community-installation relations is the extent to which land use controls are adopted by a municipality that prevent encroachment and protect the military mission. Although there may appear to be no direct incentives offered by the Army, such as grants or funding, there may be indirect benefits that deal with the employment base of the Army installation, size of the tax digest, economic contributions to the local economy, and other benefits.

CHAPTER 3: SPECIAL TOPICS AND SOURCES OF INFORMATION

This chapter briefly describes some of the resource personnel and materials available to assist the noise program manager. Because organizations and functions change, the information presented here should be used only as a starting point for obtaining current information.

SOURCES OF INFORMATION AND ASSISTANCE

U.S. Army Center for Health Promotion and Preventive Medicine: Environmental Noise Program at Commander, USACHPPM, 5158 Blackhawk Road, ATTN: MCHB-TS-EEN, Aberdeen Proving Ground, Maryland, 21010-5422. The organization has been providing environmental noise expertise to DOD for over 25 years. One of the prime duties of USACHPPM is the development of noise contour maps using field data and computer simulation. The Center is in a position to advise the installation noise program manager on implementing ENMP. Call the Environmental Noise Program at DSN 584-3829 or commercial (410) 671-3829, FAX 584-1026 or 410-671-1026.

In addition to providing noise contours, USACHPPM can provide expert testimony at public meetings or in court proceedings, education/training, noise complaint management, automated noise monitoring services, advice on the effects of noise on wildlife, and advice on technology for mitigating noise problems. They can also provide technical assistance on the ENMP analysis, mitigation alternatives, noise abatement techniques for existing structures, and noise characterization measurements and standardization. Routine services are provided free-of-charge to the requesting installation/MACOM. More extensive services may require additional funding from the requesting installation. USACHPPM is also responsible for maintenance of the MicroBNOISE computer model, the U. S. Air Force NOISEMAP computer model, the Small Arms Range Noise Assessment Model (SARNAM) (U.S. Army 1996), several other specialized models for the Army.

U.S. Army Construction Engineering Research Laboratory: Assistance on experimental or innovative technology on the effects of noise on wildlife, measurement of noise, and for mitigating noise is available from the USACERL, Champaign, Illinois, 61826-9005. Ask for the Acoustics Research Team Leader at (800) USA-CERL. Program Managers for new weapons systems or helicopters can fulfill regulatory requirements for collecting baseline noise data by arranging the noise measurements with USACERL. USACERL is responsible for modification and improvement of the BNOISE computer model and the Small Arms Range Noise Assessment Model (SARNAM). They are also responsible for the improvements to the helicopter data base in the NOISEMAP computer model.

The Institute for Water Resources (IWR): The Institute for Water Resources (IWR) has extensive experience and expertise in the public involvement phases of noise management. Their report *Reducing Environmental Noise Impacts: A USAREUR Noise Management Program Handbook* is a very useful primer for explaining the noise program to installation personnel and the public (Feather and Shekell 1991). They have also published reports on resolving noise complaints and noise management approaches, which are listed in the reference section at the end of this handbook. Their public involvement experts can be reached at (703) 355-3090.

TECHNICAL LITERATURE

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) and U.S. Army Construction Engineering Research Laboratory Reports: These are too numerous to summarize separately. USACHPPM reports are releasable only by the MACOM or installation requesting the study. Contact USACHPPM for a list of past reports on your particular installation. As the Army's lead laboratory in environmental noise research, USACERL publishes reports approved for public release. Contact USACERL for a list of available reports. In addition both USACHPPM and USACERL have very large reference libraries on environmental noise and acoustics.

Federal Agency Review of Selected Airport Noise Analysis Issues:

Available from:

FICAN
Alan Zusman, Chairman, Specialist for Airport Planning
Office of the Chief of Naval Operations
200 Stovall Street
Hoffman II, Room 11N65
Alexandria, VA 22332

In 1990, FICON was formed to review Federal policies that govern the assessment of airport noise impacts. The committee consisted of representatives from DOT, DOD, DOJ, VA, HUD, EPA, and CEQ. Upon release of this report, the committee's work was complete and it was terminated. The committee reviewed the existing scientific measurement techniques for assessing noise impacts, the Federal policies that govern assessment of airport noise impacts, and the legal aspects of current and proposed Federal policies. Their report presents a series of technical and policy recommendations regarding the measurement of noise, health and welfare effects, environmental degradation/impact, land use planning, education of the public, and noise considerations during the NEPA process. It is a definitive "must have" reference that no Army noise manager should be without.

Guidelines for Considering Noise in Land Use Planning and Control:

Available from:

Federal Interagency Committee On Urban Noise
U.S. Department of Transportation
400 Seventh Street
Washington, DC 20590

This guideline was initially prepared in response to President Carter's environmental message to Congress when he announced a new initiative to reduce urban noise. In response, the Federal Interagency Committee on Urban Noise was established to coordinate various programs designed to encourage the location of noise-sensitive development away from major noise sources.

These guidelines were the first coordinated effort at the Federal level of all agencies with some interest or responsibility for noise and land use planning. Participants in establishing this policy included the DOT, HUD, EPA, DOD, and the VA.

A major product was the recognition of the DNL as the appropriate metric for assessing land use impact and compatibility. Suggested land use compatibility guidelines in terms of noise zones were developed for all categories of land use, based on the Standard Land use Classification Manual (SLUCM)(FICUN 1980), developed earlier by the Housing and Home Finance Agency. These criteria are used for review purposes by the agencies in determining grant compliance by applicants.

Sound Level Descriptors for Determination of Compatible Land Use:

May be purchased from:

American National Standards Institute (ANSI)
Accredited Standards Committee 512, Noise Standards Secretariat
c/o Acoustical Society of America
11 W 42nd Street
New York, NY 10036
(212) 642-4900
(212) 764-3274

This standard, ANSI S12.40 (1990), was initially developed in 1980 by the S3-55 (S1) Committee for Land Use Planning with Respect to Noise. Both acoustical and nonacoustical factors must be considered in preparing a descriptor for land use planning purposes. The DNL was selected as the appropriate descriptor or metric. However, its application in terms of duration depends upon the event. For example, an annual DNL is desired but certain activities may occur occasionally (e.g., outdoor concerts), making it necessary to change the period of duration.

Compatibility of various human uses of land within the acoustical environment is assessed under this standard by use of the yearly DNL outdoors. The DNL in dB, is a 24-hour average sound level after the addition of 10 dB to sound levels during the night. Definitions are given in the standard for related physical quantities that are useful in determining DNL by measurement or prediction. For a land use that does not extend over a full year, there is a provision for judging the compatibility of the particular land use in relation to the average sound level during the relevant periods.

An Appendix provides guidance to local authorities in designating land uses compatible with existing or predicted yearly DNLs. Ranges of yearly DNLs are outlined, within which a specific dividing line of compatibility may be drawn by the local authority, considering differences in the sound level outside and inside buildings as constructed in that locality and giving consideration to local living habits. The ranges of sound levels encompass some of the statistical variability of large groups of people as they respond to noise.

All of these criteria apply to outdoor conditions. The criteria do not consider the cost or technical feasibility associated with adopting a specific DNL for a community. These are, however, similar to criteria established by Federal agencies regarding noise.

Fly Neighborly Guide:

Available from:

Fly Neighborly Committee
Helicopter Association International
1635 Prince Street
Alexandria, Virginia 22314
(703) 683-4646

The 1992 Fly Neighborly Guide is published under the auspices of the Helicopter Association International (HAI) to promote helicopter noise abatement procedures. The Fly Neighborly program is a voluntary noise reduction program designed to be implemented worldwide by local helicopter operators, large and small. This program includes all types of civilian, military, and governmental helicopter operations. Although designed primarily for nonmilitary purposes, the document has general applicability to all helicopters, depending somewhat upon the mission.

In the fall of 1988, the FAA agreed to withdraw its Notice of Proposed Rulemaking (NPRM) on helicopter noise while technical data were being acquired, with the understanding that the helicopter industry would implement a voluntary noise reduction program.

Clearly, new technology is creating quieter, more advanced equipment and this equipment will eventually be commercially available. Until then, the Fly Neighborly program offers technical information necessary for helicopter operators to use current equipment as quietly as is practical and to communicate to the public their efforts to make helicopter operations compatible with nearly all land uses. The Fly Neighborly program addresses noise abatement and public acceptance objectives with programs in the areas of pilot and operator awareness, pilot training and indoctrination, flight operations planning, public acceptance and safety, and sensitivity to the concerns of the community.

The Fly Neighborly Guide is intended to serve as a guide only and is by no means comprehensive. The guidelines are intended to assist pilots, operators, managers, and designated Fly Neighborly officers to establish an effective, self-sustained Fly Neighborly program. The flight procedures and concepts outlined must be further tailored to suit local needs, and to ensure that local or regional organizations cooperate to develop a strong, well-organized, and disciplined approach to achieving Fly Neighborly objectives.

This guide is divided into seven sections. The first section deals with pilot training and related noise abatement procedures. The second section describes what operators can do to promote noise abatement operations. The third section is designed to deal with community concerns and issues of public acceptance. An appendix explains the causes of helicopter noise. A glossary defines the acronyms used in the document, and the last two sections provide names, addresses, and phone numbers of helicopter manufacturers and regional affiliate members of HAI.

Noise Regulation Report:

May be purchased from:

Business Publishers, Inc.
951 Pershing Drive
Silver Spring, MD 20910-4464
(301) 587-6300

Check with the publisher for the current subscription rate.

The Noise Regulation Report is published twice monthly in metropolitan Washington, DC. The length of each issue varies, but ranges in size from 6 to 12 pages. All aspects of noise are covered, including both occupational and environmental noise subjects.

The focus of the newsletter is primarily on activity associated with the Federal government and regulations, policies, and programs that are underway or proposed. Occupationally-related industrial noise subjects receive considerable coverage, particularly as they relate to OSHA. Approximately one-third of the report addresses occupational noise issues.

There is broad coverage of Federally related environmental noise activities including those from the DOT, HUD, EPA, FAA, the FHA, and DOD. Military-related noise and control is covered to some extent. State activity is also covered, ranging from noise control programs and regulations to the status of litigation. A section on local regulations is also featured in each issue, presenting information about municipalities and their efforts to address noise problems.

A news brief section highlights research activity, publications available, computer software, and the like. In addition, a calendar of forthcoming event lists professional societies, short courses, and other educational opportunities.

Airport Noise Report:

One other noise-specific newsletter of interest is the *Airport Noise Report*. It specializes in environmental noise, providing more in-depth coverage than the *Noise Regulation Reporter*. It does not address occupational noise. The *Airport Noise Report* is a spinoff of the Bureau of National Affairs report that no longer covers this subject. The *Airport Noise Report* is published 25 times per year at 43987 Urbancrest Court, Ashburn, Virginia 22011, (703) 729-4867.

Internet Links Information and reports are available on a number of home pages.

FICAN - http://www.fican.org/

CHPPM - http://chppm-www.apgea.army.mil

Noise Pollution Clearinghouse - http://www.nonoise.org/

TRAINING

The primary sources of environmenal noise training within the DOD are:

U.S. Army Center for Health Promotion and Preventive Medicine
Environmental Noise Program
ATTN: MCHB-TS-EEN
5158 Blackhawk Road
Aberdeen Proving Ground, Maryland 21010-5422
(410) 671-3829

Headquarters, U.S. Air Force Center for Environmental Excellence
ATTN: ECC/Comprehensive Planning
3207 North Road
Brooks Air Force Base, TX 78235-5363
210-536-5641

U.S. Navy

Although there is currently no environmental noise training listed the Army's Directory of Environmental Training Courses is a useful reference. The directory is revised yearly and can be ordered by contacting the Environmental Training Resource Center, U.S. Army Engineer Division Huntsville, ATTN: CEHND-TD-ET, Box 1600, Huntsville, AL, 35807-4301. The Resource Center can also be reached by calling (205) 722-5883 or faxing (205) 722-5896.

APPENDIX A: UNDERSTANDING THE EPA NOISE DESCRIPTOR, AVERAGE DAY-NIGHT SOUND LEVEL (DNL)

WHY USE THE AVERAGE DAY-NIGHT SOUND LEVEL (DNL)?

The intent of this appendix is to provide enough detail to prepare an environmental manager to defend the EPA's average day-night level (DNL) in public meetings. Over twenty years of experience explaining the DNL in public meetings has taught Army noise experts that "average noise" is an unpopular idea. Yet, the concept is grounded in some good science and a person who truly understands that science should have no problem defending noise averaging.

The idea that Army experts should know how to defend a noise descriptor endorsed by the EPA might sound a little odd, but it makes sense in the context of noise control regulation in the United States. EPA's involvement in environmental noise began in 1972 with the passage of the Noise Control Act (U.S. Congress 1972). Its involvement ended in 1982 when the Office of Noise Abatement and Control (ONAC) lost all funding. The legal implications of the demise of ONAC are documented in a November 1991 report from the Administrative Conference of the United States, entitled *The Dormant Noise Control Act and Options to Abate Noise Pollution* (Shapiro 1991). In common parlance, the report describes a "Catch 22." The practical implication for environmental managers is that their EPA contacts are unlikely to have any substantive knowledge of environmental noise assessment.

Describing Noise: In fulfilling the Congressional mandate to develop a Federal noise descriptor, the EPA studied State and local noise laws as well as those of other nations. The descriptor recommended was borrowed from the countries of northern Europe. A number of these countries (Norway, Sweden, Denmark, Germany) had begun to use a measure known as "equivalent level" or LEQ. The DNL is a variant of LEQ.

In its "Levels Document" (EPA, 1974), the EPA listed seven reasons for adopting the LEQ/DNL descriptor:

1. The measure should be applicable to the evaluation of pervasive long-term noise in various defined areas and under various conditions over long periods of time.
2. The measure should correlate well with known effects of the noise environment on the individual and the public.
3. The measure should be simple, practical, and accurate. In principle, it should be useful for planning as well as for enforcing or monitoring purposes.
4. The required measurement equipment, with standardized characteristics, should be commercially available.
5. The measure should be closely related to existing methods currently in use.
6. The single measure of noise at a given location should be predictable within an acceptable tolerance, from knowledge of the physical events producing the noise.
7. The measure should lend itself to small, simple monitors that can be left unattended in public areas for long periods of time.

The measure adopted by the EPA meets all seven criteria.

Describing Noise Effects: Six of the criteria refer to the physical measurement of noise. One refers to the psychophysiological effect of noise (i.e., #2). Originally, Congress had directed the EPA to protect "all Americans from noise that jeopardizes their public health and welfare," but health effects, other than hearing loss, were not quantifiable. Instead, the EPA used five levels of "community response" (no reaction; sporadic complaints; wide spread complaints or single threat of legal action; several threats of legal action or strong appeals to local officials to stop noise; and vigorous action).

Federal agencies, especially the DOD, wanted an objective way of deciding whether noise levels were acceptable or unacceptable. They found a solution when a prominent U.S. acoustical scientist, Dr. Theodore Schultz, published Synthesis of Social Surveys on Noise Annoyance (Schultz 1978). Schultz reviewed data from social surveys concerning the noise of aircraft, street traffic, expressway traffic, and railroads. Going back to the original published data, the various survey noise ratings were translated to DNL and an independent judgment was made, where choice was possible, as to which respondents should be counted as "highly annoyed." The results of 11 of these surveys showed a remarkable consistency. Dr. Schultz proposed that the average of the 11 curves be used to predict community annoyance due to transportation noise of all kinds.

"High annoyance" is another way to describe the adverse effects of environmental noise, alongside health effects and complaints. These three effects are independent. High annoyance cannot be used to predict complaints and vice versa. People in the Zone III from aircraft noise (such as children attending school near Los Angeles International Airport) can show cardiovascular and psychological changes even though they aren't complaining about the noise.

SCIENTIFIC EVIDENCE

This section might be subtitled "Defending the DNL." The defense of DNL begins with the defense of the equivalent level (LEQ, $_{LEQ}$). The LEQ is a measure in which we take the decibel levels of a noise that is varying over a period of time and equate it to a steady noise having the same acoustical energy over the same period of time. Acousticians refer to this as *the equal energy principle*.

An advantage of LEQ is that it provides a way to combine three important annoyance factors into a single number. These three factors are: (1) the maximum loudness of noises, (2) their durations, and (3) the number of annoying sounds.

Maximum Loudness: The louder the noise, the more we are annoyed. When noise is filtered through the A-scale of a sound level meter (a scale that mimics the sensitivity of human hearing), the decibel reading gives a fairly accurate estimate of subjective loudness. For example, most people experience a 10 dB increase in the A-weighted level of an aircraft flyover as a "doubling" of loudness; a 20 dB change is experienced as a quadrupling of loudness. Maximum loudness refers to the highest level registered on the meter.

Duration: The longer a loud sound lasts, the more we are annoyed. For example, a helicopter heard for several minutes can be more annoying than a jet flyover even though the maximum level of the jet is higher. Under the rules of *equal energy*, a doubling of duration increases the annoyance by the same amount as a 3 dB increase in maximum level.

Number of Annoying Sounds: The more times we hear a loud sound, the more we are annoyed. If 10 UH-1H helicopters fly over a house, the occupants are more annoyed than from 1 Huey flyover. Under the rules of *equal energy*, a doubling of the number of equally intense noises increases the annoyance by the same amount as a 3 dB increase in maximum level.

A convincing demonstration of the validity of LEQ was a community survey of helicopter noise annoyance conducted under controlled noise exposure conditions and published by the National Aeronautics and Space Administration (NASA)(Fields and Powel 1987). Residents living in one of the helicopter flight corridors leading into Fort Eustis were repeatedly interviewed about daily noise annoyance reactions on days when helicopter noise exposures had, without the residents' knowledge, been controlled for study design purposes. A day's exposure consisted of 1 or 2 or 4 or 8 or 16 or 32 flights of a UH-1H or UH-60A helicopter at an altitude of either 500 or 1500 feet. (The altitude difference equates to a 10 dB change.)

From Equivalent Level (LEQ) to Average Day-Night Sound Level (DNL): LEQ can be calculated over any period of time. Beginning in the 1950s, acoustical scientists studying airport noise concluded that communities respond to nighttime noise as if it were 10 decibels more annoying than daytime noise. As a result, most countries add a 10 dB penalty to noise made at night. Recent studies have confirmed that this penalty is a reasonable one.

The nighttime penalty adjusts for all the factors that make nighttime noise more annoying: sleep disturbance, more people being at home more people engaged in quiet activities, and less outdoor background noise. Some countries try to separate these factors by introducing a "quiet time" penalty. In Germany, the 10 dB penalty is applied to the 8 hours between 2200 and 0600; the 6 dB "quiet time" penalty is applied from 0600 to 0700 and from 1900 to 2200 and integrated into the 16-hour daytime LEQ. Separate criteria are then applied to daytime and nighttime LEQs.

In endorsing the DNL, the EPA took a much simpler approach than the German regulators. To calculate the DNL, a 10 dB correction is added to the 9-hour LEQ between 2200 and 0700. This adjusted LEQ is then energy-averaged with the 15-hour daytime LEQ to give a 24-hour DNL.

Two Types of Day-Night Sound Level (DNL): There are two kinds of DNL: the A-weighted DNL that forms the basis of the Schultz curve and a C-weighted DNL for assessing the sounds of heavy weapons, sonic booms and other explosions. The arithmetic for calculating the DNL is the same in either case. The difference is in the weighting scale used to measure the noise.

Five Factors in Annoyance: In summary, the DNL allows the environmental manager to combine five major factors in noise annoyance into a single index. Three of these factors (loudness, duration and number) are pulled together by the LEQ; the fourth, time of day, is incorporated through the nighttime penalty in DNL. The fifth, the nature of the disturbance, is incorporated through the use of different measurement procedures for transportation noise and explosive noise.

SINGLE EVENTS AND COMPLAINTS

At the beginning of this chapter, we warned environmental managers that the DNL comes under heavy bombardment when presented in public meetings. People just don't like the idea of averaging. For some, the DNL is too abstract; they want to know how loud the noise will be. For others, the DNL doesn't describe their experience. For example, DNL is irrelevant to a mother upset about a child awakened from naps by infrequent low-level flyovers. Similarly, the DNL is irrelevant to an antique collector whose porcelain fell from a shelf because of the vibrations from artillery training. These "exceptions to the rule" can only be addressed by studying the levels of individual noise events.

Environmental noise experts use three measures to describe the noise of single noise events: maximum level, linear peak, and sound exposure level. At most Army installations, sound level meters capable of measuring maximum level are available in the Preventive Medicine section of the medical facility. In some cases, sound level meters capable of measuring linear peak or sound exposure level are also available.

Maximum Level: Maximum level (L_{max}) is the highest decibel registered on a sound level meter during a noisy event, such as an aircraft flyover. Research conducted in Sweden and other Scandinavian countries has demonstrated that a good predictor of annoyance at airfields with 50 to 200 operations per day is the L_{max} of the three noisiest events each week. Table A-1 shows the relationship between L_{max} of aircraft and percentage of highly annoyed people published in two Swedish studies (Rylander et.al 1974, Rylander and Bjorhman 1988).

Table A-1: Percentage of Population Highly Annoyed by Aircraft Noise

Maximum level, dBA	Percentage Highly Annoyed
70	5%
75	13%
80	20%

85	28%
90	35%

While there is no evidence that the relationship in table A-1 would be applicable to the operations on flight tracks or NOE corridors with fewer than 50 operations per day, the relationship provides some indication of the percentage of people who might be annoyed.

Linear Peak: Linear peak is a useful measure for weapons noise, but it can only be measured with a "precision impulse" sound level meter or a digital circuit that samples fast enough to capture the instantaneous peak of the pressure wave. The measurement of peak is also sensitive to the type of microphone used, so before attempting to measure blasts, environmental managers should discuss their equipment with the experts at USACHPPM or USACERL.

Table A-2 provides guidelines (Pater 1976) on how to interpret linear peak. They were developed by the Naval Surface Warfare Center at Dahlgren, VA. These guidelines for delaying tests at Dahlgren are based on more than 10 years of experience using meteorological forecasts. These levels resulted from the best compromise between cost, efficiency of range operations, and good community relations. For rapid fire test programs or programs that involve many repetitions of impulse noise, reduce the sound levels in Table A-2 by 15 dB peak.

Table A-2: Impulse Noise Guidelines

Sound Level, dB Peak	Risk of Complaints	Action
less than 115	low risk of noise complaints	Fire all programs.
115 - 130	moderate risk of noise complaints	Fire important tests. Postpone noncritical testing, if feasible.
130 - 140	high risk of noise complaints, possibility of damage	Fire only extremely important tests.
greater than 140	Threshold for permanent physiological damage to unprotected human ears — High risk of physiological and structural damage claims	Postpone all explosive operations.

A successful example using these guidelines took place at McAlester Army Ammunition Plant in the late 1980s. Faced with the task of destroying unstable "Kamikaze ammunition" that had been in storage since World War II, demolition range personnel had no choice but to detonate large charges (up to 260 pounds of explosive weight) without burial. During worst case meteorological conditions, adjacent home owners experienced building vibrations that they considered unacceptable. Vigorous community action followed, and U.S. Bureau of Mine experts were called in to conduct a 1-year study of ground borne and airborne vibrations. The study established the range of linear peak levels generated from the demolition ground. To reduce the incidence of "worst case" levels, the Commander established a Standard Operating Procedure in which a smaller test charge would be detonated prior to each day of demolitions. Technicians measured the peak level of the test charge at two points in the community. If the peak level fell within acceptable limits, the series of demolitions would proceed. If not, the detonating cord was disconnected, the firing circuits shorted, and a guard posted until the next

day. [In the early 1990s, McAlester AAP replaced this manual procedure with automated online monitors.]

Sound Exposure Level (SEL): The Sound Exposure Level (SEL) provides a way of looking at the total noise event, not just L_{max}. In calculating SEL, the acoustic energy during the time that the noise level is within 10 dB of L_{max} is treated as if it had all been received within a single second. One way of using the SEL is for predicting sleep disturbance. The FICON recommended dose-response relationship for interim use (FICON 1992).

The C-weighted SEL is also used to measure blast noise. This measure can be approximated by setting a sound level meter to C-weighting and slow meter response. The guidelines in table A-2 can be converted to C-weighted SEL by subtracting 25 dB.

NOISE COMPLAINTS

The primary use of single event measures is to investigate complaints. When experts at USACHPPM and USACERL studied all the noise complaints received by the Army during 1 year, they found that complaints were generated by short-term increases in the DNL, not by the DNL itself. Their study, which was published in the Journal of the Acoustical Society in 1983 (Luz et. al. 1983), also documents differences between aircraft and blast noise complaints.

Unlike "high annoyance," which Schultz found to be independent of background, complaints are sensitive to the background DNL. An important example of this sensitivity surfaced in 1987 when the FAA implemented the Expanded East Coast Plan (EECP). The EECP was a revision to air traffic control routes affecting traffic from Boston to Miami and as far west as Chicago. The plan was instituted because of delays in the three New York/New Jersey airports (Newark, Kennedy, LaGuardia). Delays in these airports were causing delays over much of the United States. By increasing the number of air routes and lowering flight altitudes over western New Jersey, the FAA was able to decrease delays by 34 percent. At the same time, people living in quiet rural areas began hearing an almost continuous background of aircraft at a low decibel level. Nearly 6,000 individuals objected vigorously to the EECP, many living as far as 30 to 40 miles from Newark. The most vigorous action came from the community of Long Valley, where 6 percent of the population complained after the DNL increased from an annual average of 42 dB to 49 dB.

The political activism arising out of the EECP was a major impetus for the creation of the FICON in 1990. This was the first time that Federal agencies had met about environmental noise since the demise of the EPA's ONAC. Two policy recommendations from the 1992 FICON report represent tentative moves toward consideration of background DNL, at least for aircraft noise. These recommendations are listed in the two boxes below. There is further discussion of the importance of background DNL in the discussion of "Noise in Protected Areas" later in this appendix.

FICON Recommendation 1: If screening analysis shows that noise-sensitive areas will be at or above DNL 65 dB and will have an increase of DNL 1.5 dB or more, further analysis should be conducted of noise-sensitive areas between DNL 60-65 dB having an increase of DNL 3 dB or more due to the proposed airport noise exposure.

FICON Recommendation 2: If the DNL 65 dB screening test calls for further analysis between DNL 60-65 dB, agency mitigation options will include noise-sensitive areas between DNL 60-65 dB that are projected to have an increase of 3 dB or more as a result of the proposed airport noise exposure.

COMPUTER MODELS FOR DAY-NIGHT SOUND LEVEL (DNL)

There is only one way to conduct the type of analysis recommended in the above two boxes — by means of a computer model. The primary means of assessing environmental noise is through computer simulations, since direct measurement of noise levels is often impractical, expensive, and inconclusive. Computer simulations can be summarized on installation land use maps to be incorporated into the installation master plan and NEPA documentation. The primary computer models used to predict DNL are NOISEMAP, ROUTEMAP, and BNOISE. The Army's primary operator of these models is the USACHPPM.

NOISEMAP: The NOISEMAP computer model is the official DOD model for military airfield noise. Earlier versions of NOISEMAP, beginning in the 1970s, ran on mainframe computers. Currently, DOD agencies are using PC-based versions of the NOISEMAP 6.0 computer series. The required inputs to the program are the location of the flight tracks and the number of each type of aircraft using each flight track. The BASEOPS program is used to enter these data into the NOISEMAP input file. These required inputs are obtained from airfield operational data. A revised Army helicopter database was added to NOISEMAP in 1993.

ROUTEMAP: In addition to the noise along the boundaries of airfields and airbases, the DOD is responsible for assessing noise along military flight corridors and in Military Operations Areas. The noise contours for the corridors used for entering and exiting Army installations are generated using ROUTEMAP. ROUTEMAP is also used for predicting noise exposure from aircraft operations on military training routes. The inputs to the model are the altitude, power setting, speed, and number of operations by aircraft type for a 1-month period.

The ROUTEMAP model computes and plots the LEQ, the ADNL, the onset rate-adjusted monthly day-night level (DNMRL), and the probability of high annoyance. These levels are computed for distances perpendicular to the corridor.

The USAF research supporting the use of DNMRL included only fixed wing aircraft. Until it is clear that the model applies to helicopters as well, the USACHPPM staff will continue to use a simplified corridor model known as HELIOSLICE.

BNOISE: The noise simulation program used to assess heavy weapons noise is BNOISE. The BNOISE program requires operational data concerning type of weapons fired from each range or firing point including demolitions, the number and type of rounds fired from each weapon, the location of targets for each range or firing point and the amount of propellant used to reach the target. Existing records on range utilization along with reasonable assumptions are used as BNOISE inputs.

There are some cases when BNOISE does not give a correct prediction because of software limitations:

- It does not accept explosive weights greater than 999 pounds.
- Measurements of large detonations at Sierra Army Depot conducted by the USACHPPM showed that BNOISE over predicts the size of the noise zones for weights greater than 375 pounds.
- It does not correct the noise zones for the local topography.

Where topography has to be considered, the experts at the USACHPPM use a single event model known as SHOT. The topography algorithm in SHOT was derived from USACHPPM monitoring studies at Forts Knox and Indiantown Gap. The model was verified with the results of extensive monitoring at Picatinny Arsenal and Navajo Depot Activity. Although the SHOT model cannot be used to generate a map of noise contours as does BNOISE, the terrain correction between a firing point and a receiver point is useful in knowing the amount of error in the BNOISE predictions.

The SHOT model can be used to predict the expected mean linear peak sound level and the distribution of the levels about this mean for proposed detonation weights and selected receiver locations. This feature is particularly useful in predicting complaints.

The propagation algorithm in SHOT is based on an extensive measurement project by the USACERL at Fort Leonard Wood with analysis at USACHPPM. These measurements of 5-pound charges are corrected for the different charge weights with the relationship used by USACERL in their linear peak sound level model. The accuracy of this model for large detonations was checked with the measurements taken at Sierra Army Depot. For the 29 measurements taken at Sierra, the mean level predicted by the SHOT model under predicted the measured levels by an average of 1.4 decibels.

TRAFFIC NOISE In 1996, the Federal Highway Administration (FHWA) began finalizing and testing its new highway-noise computer program, called the FHWA Traffic Noise Model (FHWA TNM). TNM computes highway traffic noise at nearby receivers and aids in the design of roadway noise barriers. As sources of noise, it includes 1994-1995 noise emission levels for automobiles, medium and heavy trucks, buses and motorcycles. The model can account for the change in vehicle levels on upgrades and accelerating away from stop signs, toll booths, traffic signals and onramp start points. It also accounts for the change in levels with speed. In contrast to earlier computer models that calculated the "lump sum" value of the A-weighted level at different distances, the TNM calculates the propagation for each 1/3 octave band in the noise signal. After the level in each 1/3 octave band is calculated, the software adds up the results to give the "lump sum" A-weighted level. By breaking the acoustic signal down in this way, the TNM is able to provide much better predictions of the following factors than available with earlier models:

- Divergence
- Atmospheric absorption
- Intervening ground: its acoustical characteristics and its topography
- Intervening barriers: walls, berms and their combination
- Intervening rows of buildings
- Intervening areas of heavy vegetation

TNM operates in a Windows environment and is easily interfaced with a Geographic Information System (GIS).

SMALL ARMS RANGE NOISE ASSESSMENT MODEL In 1997, USACERL and CHPPM began testing a new small arms model, SARNAM, which was developed at USACERL with the assistance of USACHPPM. The model calculates and plots noise contours for small arms ranges complexes. It includes consideration of type of weapon and ammunition (including spectrum and directivity and both muzzle blast and projectile bow shock), number and time of rounds fired, range attributes such as size and barriers, propagation conditions, penalties, metrics and long-term assessment period and procedure. SARNAM is constructed in a modular fashion to facilitate future enhancements, features a graphical interface, and operates in a Windows environment Similar to TNM, the SARNAM model calculates the separate contribution of each 1/3 octave band in the signal and sums the result to get the A-weighted level

Before and After Noise Studies: The computer models provide the tools for commanders to carry out their NEPA responsibility in respect to environmental noise. By running a simulation with existing operations and then comparing to a simulation with proposed operations, the technician can show the amount of change expected from a new range, new airfield, and so on. When an increase in noise levels is found, the computer models can also be used to explore ways to mitigate the noise.

MONITORING OF DAY-NIGHT SOUND LEVEL (DNL)

Monitoring can never be used to generate a noise contour and by policy the Army does not normally consider on-site monitoring except where needed to address a complaint or verify noise levels that have produced a major public controversy. There are, however, four circumstances where on-site monitoring of the DNL may be useful. These are checking the accuracy of a noise contour at selected points, defining the DNL when the model is known to be inaccurate, defining the DNL when no operational data are available, and defining the baseline DNL. Most automated monitoring of Army environmental noise is conducted by experts at the USACHPPM. To lower costs, the USACHPPM experts sometimes train personnel at the installation to collect the data from their monitoring equipment.

Checking Accuracy: Experience has shown that DOD computer models usually provide accurate estimates of DNL within a few kilometers of the noise sources. However, uncertainty increases with distance from the source. Army policy handles the uncertainty by recommending that the contour be located at a convenient geographical boundary, such as a stream or road. If the public questions the accuracy of the contour, automated noise monitoring may be in order.

Monitoring is also advisable if the environmental manager questions the operational data. Because there are no regulations requiring airfield/airspace managers and range control officers to keep the data needed for the computer models, the data are sometimes “educated guesses.” Automated monitoring can show whether the guesses are reasonable estimates.

It is best to schedule automated monitoring during “worst case” periods, since the LEQ is biased toward the highest levels. For example, if the shape of the contour is defined by artillery firing, monitoring should be scheduled during a large artillery Army Training Evaluation Period. For helicopter flight corridors, USACHPPM experts suggest locating a series of five monitors on a line perpendicular to the flight corridor with the middle monitor centered on the flight track.

This data can be used by comparing noise levels registered simultaneously at adjacent monitors, which gives an indication whether the aircraft flew in the corridor.

Dealing with Known Inaccuracy: An example of a known inaccuracy in BNOISE is the effect of the Chesapeake Bay on the propagation of heavy weapons noise from Aberdeen Proving Ground to the Eastern Shore of Maryland. Just as the low frequency of a fog horn propagates efficiently over water, the low frequency of a blast from Aberdeen Proving Ground's main front reaches shoreline properties with no attenuation from ground or vegetation. Accurate operational data on the exact times, location, and type of firing add to the value of this type of monitoring study.

No Operational Data: When nothing is known about the noise sources, DNL can be defined with reasonable statistical accuracy at an airfield by sampling for 1 week in each of the four seasons of the year. For a limited source, such as a highway, 2 weeks of monitoring should give an adequate estimate of the long-term average. Unfortunately, the minimum monitoring time for heavy weapons noise is in the order of 3 to 4 months. For this reason, it is best to limit blast noise monitoring to periods of "worst case" operations.

Some Army installations have purchased on-line blast noise monitoring systems. Automated monitors located at permanent sites feed in to a central computer at range control, so that range operators can identify times when blast noise exceeds the complaint guidelines listed earlier in Table A2. When care is taken to screen the data for artifacts (e.g., wind gusts), the DNL may be calculated from several months worth of records.

Defining the Baseline Day-Night Sound Level (DNL): In the policy recommendations of the FICON discussed earlier in this chapter, an increase is considered significant if a DNL above 65 increases by 1.5 dB or a DNL between 60 and 65 increases by 3 dB. Automated monitoring is useful in defining the baseline.

An example of baseline monitoring was a study of the Army family housing area at Charles Melvin Price Support Center, Granite City, Illinois, published by the USACHPPM in 1991. Located inside industrial zoning, the housing area was subject to noise from commercial aircraft, cars, trucks, river traffic, rail traffic, industrial operations and Reserve helicopter flight training. Computer modeling was not feasible. Instead, the 1990 baseline was determined from 10 days of 24 hour monitoring data collected by the Support Center environmental manager during each of the four seasons of the year.

The public sometimes asks for baseline noise monitoring as a guarantee that an Army project will not increase noise levels in quiet areas. Post construction monitoring made with the same equipment and at the same sites can establish whether levels have increased. An example of using baseline monitoring to protect Army property was a study conducted in 1992 to 1993 by the Fort Jackson environmental manager. A comparison of "before" and "after" monitoring data showed the effect of a new interstate on family housing and troop barracks. Documentation in the form of an USACHPPM report set the stage for the Commander to ask the State to pay for noise barriers if levels were to increase to a DNL of 65.

NOISE IN PROTECTED/SENSITIVE AREAS

Public Law 100-91 (U.S. Congress 1987) required the U.S. Department of Agriculture Forest Service and the National Park Service to assess aircraft noise impacts on outdoor recreationists in National Parks and Forest Service wildernesses. This legislation was in response to the ongoing environmental deterioration in the nation's protected areas. The major noise concern was commercial helicopters, such as those in Hawaii's Volcano National Park and Arizona's Grand Canyon National Park.

In fulfilling their mandate, the U.S. Forest Service and National Park Service started fresh with no anchoring to the existing Federal guidelines on DNL. Instead, these agencies focused on audibility, noticeability, and detectability. Because these variables depend on background noise, the Forest Service funded contractors to develop models predicting the background noises of nature, such as rivers, wind in the trees and insect noise.

Since some Army training takes place in wilderness areas controlled by other agencies of the Federal government, a policy based on the audibility of sound could have an effect on future training. Environmental managers are advised to keep abreast of any policy changes.

Another concern about noise in protected areas is its effect on wildlife. Since DNL is a measure of human annoyance, it cannot be applied to animals. As a general rule, wildlife adapt to military noise. In fact, many endangered species are to be found down range and in impact areas where noise is highest but the presence of humans is lowest. Bibliographies on the effects of noise on animals are available as part of the North Atlantic Treaty Organization-Committee on Challenges of Modern Society's Intenational Bibliograpgy on Noise (IBON) database (maintained by U.S. Air Force). Advice on the effects of Army noise on animals is available from the Environmental Noise Program, USACHPPM.

GLOSSARY

Note: This glossary contains some terms that do not appear in the text of this volume, but that readers may encounter in the course of their work.

Accident Potential Zones (APZ): The area immediately beyond the end of a runway, also known as, the "clear zone," an area that possesses a high potential for accidents, and has traditionally been acquired by the government in fee to be kept clear of obstructions to flight.

Airfield Operations Officer: The source of data for NOISEMAP.

Air Installation Compatible Use Zone (AICUZ): DOD's original program that was developed in the early 1970s after losing use of some air bases because of residential encroachment.

A-Weighted Day-Night Average Sound Level (ADNL): A noise measurement scale that closely resembles the frequency response of human hearing and, therefore, provides a good indication of the impact of noise produced by transportation activities.

BNOISE: A heavy weapons noise contouring software (main frame) that was funded Army Master Planning Office in 1972 and developed by USACERL. This software was then converted for use on a personal computer in 1986.

Composite Noise Rating (CNR): A methodology for an aircraft noise assessment that was developed in 1964 through research by the U. S. Air Force.

C-weighted Day-Night Average Sound Level (CDNL): A noise measurement scale that effectively measures high amplitude impulsive noise resulting from armor, artillery, and demolition activities.

Day-Night Average Sound Level (DNL): A measure based on an annual average, that has been incorporated into Army regulations as the official procedure for assessing environmental noise.

Emissions Laws: The laws that regulate the amount of noise emitted from equipment. Regulating noise at the source is an integral part of the these laws.

Encroachment: A term that implies unguided use or development of the land surrounding a military installation.

Environmental Assessment (EA): A written environmental analysis that is prepared pursuant to the National Environmental Policy Act to determine whether a Federal action would significantly affect the environment and thus require preparation of a more detailed Environmental Impact Statement (EIS).

Environmental Noise Management Plan (ENMP): The ENMP provides a strategy for noise management at the installation. Elements of the plan include education, complaint management, noise and vibration mitigation, the "Fly Neighborly" program, noise abatement, and the ICUZ program.

Environmental Impact Statement (EIS): A document required of Federal agencies by the National Environmental Policy Act for major projects or legislative proposals significantly affecting the environment. A tool for decision making, it describes the positive and negative effects of the undertaking and lists alternative actions.

Environmental Protection Agency (EPA): The Federal agency responsible for efforts to control pollution, including noise. It was established by a Presidential Executive Order in 1970.

Environmental Quality Control Committee (EQCC): A committee that absorbs the functions of the ICUZ committee at some installations.

Equivalent Level(LEQ): A method of stating noise levels in which the decibel levels of a noise that varies over a period of time are equated to a steady noise having the same acoustical energy over the same period of time.

Fly Neighborly: A voluntary noise reduction program designed to be implemented worldwide by local helicopter operators, large and small.

Helicopter Association International: An association to promote helicopter noise abatement procedures.

Heliports and Airways Committee: The committee that, along with Helicopter Association International, originally organized the Fly Neighborly program through the Heliports and Airways Committee's Fly Neighborly Steering Committee.

High Annoyance: A way to describe the adverse effects of environmental noise, along with health effects and complaints.

Installation Compatible Use Zone (ICUZ): A preventive program that addresses noise and accident potential, both on and off the Army installation. This program attempts to protect Army property from possible land encroachment that may be incompatible with the Army's mission. It is also designed to be sensitive to the community.

Joint Land Use Study (JLUS): A process that enables local governments to be more active in the land use planning process by providing grants for them to hire independent planning consultants.

Linear Peak: A useful measure for weapons noise, but it can only be measured with a precision impulse sound level meter or a digital circuit that samples fast enough to capture the instantaneous peak of the pressure wave.

Low-Noise-Emission Products: The products that emit significantly less noise than permitted by an applicable emissions standard.

Maximum Level: The highest decibel registered on a sound level meter during a noisy event, such as an aircraft flyover.

Mitigation: Measures taken to reduce adverse impacts on the environment.

National Environmental Policy Act (NEPA): This act of 1969 (PL 91-90; 42 U.S.C. 4321-4347) is the nation's charter for protecting the environment. This act requires Federal agencies to prepare an Environmental Impact Statement for every major Federal action that affects the quality of the human environment, including the impact of noise.

Noise Control Act: PL 92-574, passed by Congress to address environmental noise in 1972.

NOISEMAP: The official DOD computer model for analyzing military airfield noises.

Office of Noise Abatement and Control (ONAC): The EPA office that reviewed Federally sponsored projects, policies, and programs that dealt with the subject of noise and coordinated these activities. The office was operational from 1972 to 1984.

Public Affairs Officer (PAO): The central point of contact for all noise inquiries or complaints. The officer has primary responsibility for organizing and managing all off-post meetings and formal contacts.

Range Control Officer: The person responsible for collecting the operational data needed to generate noise contours using the BNOISE software.

Receiver-based laws: The laws that regulate the amount of noise exposure received at particular locations.

ROUTEMAP: A model that computes and plots the equivalent sound level, the onset rate-adjusted monthly DNL, and the probability of high annoyance for fixed-wing aircraft.

Sound Exposure Level (SEL): A noise exposure level that provides a way of looking at the total noise event, not just maximum level.

Staff Judge Advocate (SJA): An interpreter of State and local noise law who understands the zoning law and knows when military noise constitutes a taking of the value of a property.

ACRONYMS

ADNL	A-weighted day-night average sound level
ENMP	Army's Environmental Noise Management Plan
AEPI	Army Environmental Policy Institute
AICUZ	Air Installation Compatible Use Zone
AMC	Army Material Command
ANSI	American National Standards Institute
APZs	Accident potential zones
AR	Army Regulation
ASNA	Aviation Safety and Noise Abatement Act
CDNL	C-weighted Day-Night Average Sound Level
CERL	Construction Engineering Research Laboratory
CFR	Code of Federal Regulations
CHABA	Committee on Hearing, Bioacoustics and Biomechanics
CNR	Composite Noise Rating
DA	Department of the Army
dB	Decibels
dBA	A-weighted decibel scale
dBC	C-weighted decibel scale
DEH	Directorate of Engineering and Housing
DNL	Day-night average sound level
DNMRL	Onset rate-adjusted monthly day-night level
DOD	Department of Defense
DOT	Department of Transportation
DPW	Directorate of Public Works
ECHO	Each Community Helping Others
EECP	Expanded East Coast Plan
EPA	Environmental Protection Agency
EQCC	Environmental Quality Control Committee
FAA	Federal Aviation Administration
FHA	Federal Highway Administration
FICAN	Federal Interagency Committee on Aircraft Noise
FICON	Federal Interagency Committee on Noise
FONSI	Finding of no significant impact
FY	Fiscal year
GAO	General Accounting Office
HAI	Helicopter Association International
HQDA	Headquarters, Department of the Army
HUD	Department of Housing and Urban Development
ICUZ	Installation Compatible Use Zone
IPA	Intergovernmental Personnel Act
IWR	Institute for Water Resources
JLUS	Joint Land use Study
LAW	Light assault weapon
LEQ	Equivalent level
MACOM	Major Command
mm	Millimeter

NASA	National Aeronautics and Space Administration
NCA	Noise Control Act of 1972
NCPs	Noise compatibility programs
NEMs	Noise exposure maps
NEPA	National Environmental Policy Act
NOE	Nap-of-the-Earth
NPRM	Notice of Proposed Rulemaking
NRC	National Research Council
ODEP	Office of the Director of Environmental Programs
ONAC	Office of Noise Abatement and Control
OSHA	Occupational Safety and Health Act
PAO	Public Affairs Office
PD	Proximity detecting
PL	Public Law
RCO	Range Control Officer
SEL	Sound Exposure Level
SJA	Staff Judge Advocate
SLUCM	Standard Land use Classification Manual
TDR	Transfer of Development Rights
USAF	U.S. Air Force
USAREUR	U.S. Army Europe
U.S.C.	United States Code
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
VA	Veterans Administration
VT	Variable time

REFERENCES

ANSI. 1983. American National Standard Specification for Sound Level Meters. S1.4-1983.

ANSI. 1986. American National Standard Method for Assessment of High-Energy Impulsive Sounds with Respect to Residential Communities. S12.4-1986.

Benson, Jonathan W. 1996. Noise Control Engineering Journal, 44(6), Nov-Dec.

Berendt, R.D., E.L. Corliss, M.S. Ojalvo. 1976. Quieting: A Practical Guide to Noise Control. Washington, DC: National Bureau of Standards. Handbook No. 119.

Committee on Hearing, Bioacoustics, and Biomechanics Working Group 84. 1981. Assessment of Community Response to High-Energy Impulsive Sounds. Washington, DC: National Research Council.

Department of Defense. 1977. DOD Instruction 4165.57, Air Installations Compatible Use Zones. Washington, DC: U.S. Department of Defense.

_____. 1978. DOD Instruction 42701.M, DOD Construction Criteria Manual. Washington, DC: U.S. Department of Defense.

_____. 1991. MIL-STD 1474 (C), Noise Limits for Army Material. Washington, DC: U.S. Department of Defense.

Environmental Protection Agency. 1974. Report No. 550/9-74-004, Information on Levels of Environmental Noise Requisite to Protect Health and Welfare with an Adequate Margin of Safety. Washington, DC: Environmental Protection Agency.

Federal Aviation Administration. 1976. Aviation Noise Abatement Policy. Washington, DC: Federal Aviation Administration.

Feather, T. and T. Shekell. 1991. Reducing Environmental Noise Impacts: A USAREUR Noise Management Program Handbook. Institute for Water Resources Report 91-R-5. Ft. Belvoir, VA: Institute for Water Resources.

FICON. 1992. Federal Agency Review of Selected Airport Noise Analysis Issues. Washington, DC.

Fields, J. C. Powell. 1987. Community Reactions to Helicopter Noise: Results from an Experimental Study. Journal of the Acoustical Society of America. 82 (2), pages 479-492.

FICUN. 1980. Guidelines for Considering Noise in Land Use Planning and Control. Washington, DC: U.S. Department of Transportation.

Fittipaldi, John J., Steve D. Hottman, Richard M. Marlatt, Inga Kennedy-Tucker, Clifford R. Bragdon, Russell W. Forrest. 1980. Procedures for Conducting Installation Compatible Use Zone (ICUZ) Studies. Technical Report N-88/19.Champaign, IL: USACERL.

HAI. 1983. I Fly Neighborly. Helicopter Association International, Washington D.C.

Hottman, Steven D., John J. Fittipaldi, and Richard G. Gauthier. 1986. MicroBNOISE: A User's Manual, Technical Report N-86/12. Champaign, IL: USACERL.

Illinois Environmental Protection Agency. 1982. Noise Pollution, Section 901.106 Prominent Discrete Tones. State of Illinois Environmental Protection Agency, Amended at 6 Ill. Reg. 10960.

Luz, G. R. Raspet and P Schomer. 1983. An Analysis of Community Complaints to Noise. Journal of the Acoustical Society of America. 73 (4), pages 1229-1235.

National Association of Counties. 1979. Quiet Communities: Minimizing the Effects of Noise Through Land use Controls. Washington, DC: National Association of Counties.

Pater, 1976, "Noise Abatement Program for Explosive Operations at NSWC/DL", presented at the 17th Explosives Safety Seminar of the DOD Explosives Safety Board.

Rylander, et.al., 1974, "Re-Analysis of Aircraft Noise Annoyance Data Against the dBA Peak Concept", Journal of Sound and Vibration, Volume 36, pages 399 - 406.

Rylander and Bjorkman, 1988, "Maximum Noise Levels as Indicators of Biological Effects", Journal of Sound and Vibration, Volume 127, pages 555 - 563.

Schultz, T. 1978. Synthesis of Social Surveys on Noise Annoyance. Journal of the Acoustical Society of America. 64 (2), pages 377-404.

Shapiro, Sidney A. 1991. The Dormant Noise Control Act and Options to Abate Noise. Administrative Conference of the United States, Washington DC.

U.S. Army. 1964. Report No. 1240. Handbook for Predicting of Air Blast Focusing. Ballistics Research Laboratories, Aberdeen Proving Ground, MD.

_____. 1978. Technical Manual TM 5-803-2, Planning in the Noise Environment. U.S. Department of the Army, Washington, DC.

_____. 1981. Technical Report N-112. Use of Aqueous Foam to Migigate Demolition Noise. USACERL, Champaign, IL.

._____. 1983. Army Regulation 200-1, Environmental Protection and Enhancement. Washington, DC: U.S. Department of the Army, Washington, DC.

_____. 1986. Army Regulation 5-3, Installation Management and Organization. U.S. Department of the Army, Washington, DC.

_____ 1987. Expedient Methods for Rattle Proofing Certain Housing Components. N-87/24.USACERL, Champaign, IL.

_____. 1988a. Army Regulation 385-10, Army Safety Program. Washington, DC: U.S. Department of the Army.

_____. 1988b. Army Regulation 200-2, Environmental Effects of Army Actions. Washington, DC: U.S. Department of the Army.

_____. 1988c. Technical Report N-88/19. Procedures for Conducting Installation Compatible Use Zone (ICUZ) Studies. USACERL, Champaign, IL.

_____. 1989. Judge Advocate General Memorandum on Environmental Noise, 3 March 1989. Washington, DC: U.S. Department of the Army, Office of the Judge Advocate General.

_____. 1990. Army Regulation 95-1, Flight Regulations. Washington, DC: U.S. Department of the Army.

_____. 1990. Army Regulation 40-5, Health and Environment. Washington, DC: U.S. Department of the Army.

_____. 1991. Army Regulation Pam 40-501, Hearing Conservation. Washington, DC: U.S. Department of the Army.

_____. 1996. DRAFT, User Manual, SARNAM, Noise Contouring Tool for Small Arms Ranges. USACERL, Champaign, IL.

_____. 1997. Army Regulation 200-1, Environmental Protection and Enhancement. Washington, DC: U.S. Department of the Army, Washington, DC.

U.S. Army Environmental Hygiene Agency. 1990. Environmental Noise Study No. 52-34-0607-91, Ambient Noise Measurements, Charles Melvin Price Support Center. Aberdeen Proving Ground, MD.

_____. 1993. Environmental Noise Study No. 52-34-Q1N0-93. Assessment of Impact of I-77 on Fort Jackson Cantonment Area. Aberdeen Proving Ground, MD.

U.S. Congress. 1969. Public Law 91-190, National Environmental Policy Act. Washington, DC: United States Congress.

_____. 1970a. Public Law 91-596, Occupational Safety and Health Act. Washington, DC: United States Congress.

_____. 1970b. Public Law 91-258, Airport and Airway Development Act. Washington, DC: United States Congress.

_____. 1972. Public Law 92-574, Noise Control Act: Washington, DC: United States Congress.

_____. 1978. Public Law 95-609, Quiet Communities Act. Washington, DC: United States Congress.

_____. 1980. Public Law 96-193, Aviation Safety and Noise Act of 1979. Washington, DC: United States Congress.

_____. 1987. Public Law 100-91, National Park Overflight Act of 1987. Washington, DC: United States Congress.

University of North Carolina. 1991. Joint Compatible Land Use Policy: Recommendations to Military Jurisdictions and Local Governments in the Fort Bragg Region. Chapel Hill, NC: Center for Urban and Regional Studies, University of North Carolina at Chapel Hill.

University of Utah, 1958, Explosives Research Group Report No. 12, Measurement of Air and Ground Shock Disturbances Arising from Demolition Activities at Letterkenny Ordnance Depot.

Washington State. 1987. Maximum Environmental Noise Levels, Chapter 173-60 WAC, February 17, 1987.

Wyle Research. 1989. Guidelines for the Sound Insulation of Residences Exposed to Aircraft Operations. Prepared for Naval Facilities Engineering Command, Special Advisors for Planning Coordination, Alexandria, Virginia; Federal Aviation Administration, Office of Environment & Energy and Office of Airport Planning & Programming, Washington, DC.

INDEX